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Feasibility study for environmental product information based on life cycle approaches

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Abstract

In the recent past, several initiatives designed to reveal the carbon footprint of consumer products or provide other life cycle based environmental information have been launched. The presentation of environmental product information (EPI) may contribute to more informed purchase decisions. It would help to increase the attention given by companies to more eco-efficient products and production processes. Yet several key aspects still need clarification. This feasibility study investigates the strengths and weaknesses, the opportunities and the limits of environmental information for products in detail.

How to show environmental impacts of products?

As a first step, the authors of this study evaluate different approaches towards providing environmental information about products based on life cycle thinking. Proceeding from this evaluation we consider carbon footprint to be insufficient for environmental information and thus recommend the use of life cycle assessment (LCA) for this purpose. We show the main challenges facing the provision of meaningful information to direct consumer decisions.

Different approaches towards environmental product information

Consideration of the use and end-of-life phases of products is a special issue of EPI. These phases may be very important, depending on the type of product. However, the use phase often exhibits major variability, as it is influenced by disparate products and consumer behaviour. Furthermore, the use and final disposal of a product can only partly be influenced by the producer. We think that it is not feasible to systematically include the full life cycle in an EPI.

Inclusion of full life cycle not feasible for all products

Generally the environmental information should be shown for the product as it is bought in the shop (life cycle from cradle to shop). The impacts of the full life cycle could be shown additionally and separately if they are relevant for the total impact, e.g. for all products directly using energy. In such cases it is necessary to show the environmental impacts for a functional unit, e.g. one wash of 4kg laundry at 60 degrees in a washing machine. Application of EPI to the full life cycle is thus restricted to predefined groups of similar products with the same function.

Life cycle stages in modeling environmental product information

Furthermore, the level of decision-making addressed by the approach must be considered. Here we recommend starting with higher levels of decision-making, i.e. calculating average impacts of products groups and addressing the general differences between these groups. Consumers would thus see the relevance of different buying decisions and could e.g. compare average bread with average vegetables. After that, the approach could be refined and analyses carried out for individual products.

Guiding general decisions instead of delivering excessive detail

Communication of LCA results in a simplified form would be another issue to consider. We explain and compare different communication approaches. We suggest using the Swiss ecological scarcity method to assess environmental impacts. For simplifying communication the environmental impacts of a product should be related to overall environmental goals, and time use can be used as an understandable unit.

Impact assessment for several emissions and resource uses

Five case studies, e.g. on vegetables and mineral water, are evaluated in order to highlight the general methodological problems of an EPI approach and outline solutions how to best address them.

Case studies highlight methodological challenges

There are several obstacles to putting life cycle based environmental information for products into practice. It is questionable whether one particular approach towards environmental product information can serve all kinds of purposes, starting from supporting comparative assertions of different brands of a product offered in a supermarket to comparing different consumption patterns of households. We therefore recommend giving priority to the approach described above, which is able to address most purposes.

No perfect approach

Zusammenfassung

Ausgangslage

Weltweit steigen die Produktion und der Konsum von Gütern und Dienstleistungen und damit der Energie- sowie der Materialverbrauch immer weiter an. Damit der Umweltverbrauch durch den Konsum auf ein nachhaltiges Niveau gesenkt wird – beim Wohnen, beim Mobilitäts- und Freizeitverhalten wie bei der Ernährung – müssen Informationen bereitgestellt werden, die ressourcenschonende Kauf- und Nutzungsentscheide unterstützen.

Ausgangslage

Der Bundesrat erachtet in seiner Strategie Nachhaltige Entwicklung 2008-2011 ressourcenrelevante Informationen für Marktteilnehmende als wichtige Massnahme zur Umsetzung der sogenannten Integrierten Produktpolitik (IPP). Die IPP[1] hat zum Ziel, die Nachfrage seitens der öffentlichen Hand und von Privaten nach Produkten[2] mit hohen sozialen, ökonomischen und ökologischen Standards zu fördern. Hierbei soll der gesamte Lebensweg der Produkte, von der Planung über die Rohstoffgewinnung, die Produktion, den Kauf, den Gebrauch und die Entsorgung bzw. Verwertung, berücksichtigt werden. Im Rahmen der Umsetzung der IPP hat das BAFU eine Studie über die wichtigsten Umweltaspekte des schweizerischen Konsums und die dafür verantwortlichen Schlüsselentscheide publiziert (Känzig & Jolliet 2006). Eine zweite Studie über das Konsumverhalten und die Förderung des umweltverträglichen Konsums wurde 2010 auf der BAFU Website freigeschaltet.

Integrierte Produktpolitik (IPP)

Bereits heute helfen Energieetikette oder Nahrungsmittellabels den Konsumentinnen und Konsumenten dabei, ressourcenschonende Kauf- und Nutzungsentscheide zu treffen, doch es besteht weiterhin Handlungsbedarf: Erstens zeichnen die bestehenden Labels nur die besten Produkte in einer Produktgruppe aus und für viele Produkte gibt es noch gar keine Umweltinformationen. Zweitens erfassen existierende Informationen häufig nicht systematisch den ganzen Lebensweg eines Produktes, also vom Anbau/Rohstoffgewinnung über die Herstellung und den Transport bis zum Verbrauch und der Entsorgung. Drittens werden oft nicht alle relevanten Umweltauswirkungen berücksichtigt (wie Wasser- Bodenverbrauch, Qualitätsverlust der Ökosysteme). Der Markt ist also bezüglich des Umwelt- und Ressourcenverbrauchs von Produkten zu wenig transparent.

Ökologische Markttransparenz

Für eine umfassende Beurteilung der Umweltbelastung eines Produktes als Orientierungshilfe bei Konsumentscheidungen ist die Verbesserung der ökologischen Markttransparenz deshalb zentral. Es braucht die Bereitstellung von fachlich fundierten, relevanten und verständlichen Informationen zu den Umweltbelastungen des Konsums. Dafür braucht es Methoden und Regeln, wie Produkte und Konsumbereiche analysiert, bewertet und die Ergebnisse kommuniziert werden sollen, so dass ein umfassendes und glaubwürdiges Bild des Ressourcenverbrauchs erarbeitet werden kann („True and Fair View“). Damit soll die Nachfrage der Konsumierenden - Einzelpersonen, Unternehmungen oder die öffentliche Hand – auf Produkte mit geringeren Umweltbelastungen ausgerichtet werden. Dieses Projekt untersucht die Machbarkeit der Bereitstellung von Umweltinformationen für Produkte.

Ziel

[1] Strategie Nachhaltige Entwicklung des Bundesrats: Leitlinien und Aktionsplan 2008–2011, Kapitel 3.2, Punkt 4

[2] In diesem Bericht werden hierunter Güter und Dienstleistungen verstanden.

Fragestellung der Studie

Ausgehend von den vorher umrissenen Rahmenbedingungen soll mit dieser Studie in erster Linie die folgende Frage beantwortet werden: Wie kann man die Umweltbelastungen (d.h. die Emission von Schadstoffen, den Verbrauch von natürlichen Ressourcen und die damit verbundenen Schäden an Mensch und Natur) von Produkten erfassen und bewerten? Der Vorschlag soll die Übertragbarkeit auf unterschiedliche Produktgruppen und –sortimente beinhalten und hinsichtlich deren Umweltinformation anwendbar sein. Vorerst beschränkt sich die Untersuchung auf Produkte für Endkonsumentinnen und Konsumenten.

Hauptfrage

- Ausserdem werden erste Überlegungen dazu angestellt, wie Informationen über die Umweltbelastung von Produkten für die Konsumentinnen und Konsumenten in einer verständlichen und sachlich relevanten Form aufbereitet werden können.

Im Rahmen dieser Studie sollen dazu Antworten und Aussagen zu folgenden Punkten geliefert werden:

Detailfragen

Wie hoch ist der Aufwand zur notwendigen Datenerfassung und welche Hintergrunddatenbanken können bei verschiedenen Bewertungsmethoden verwendet werden?

Welche Einwirkungen auf Mensch und Umwelt können mit den bestehenden Bewertungsmethoden nicht angemessen berücksichtigt werden (z.B. Lärm, elektromagnetische oder radioaktive Strahlung, Biodiversität)?

Bei welchen Produkten ist eine Umweltbewertung und Umweltinformation („Umweltbepreisung") aussagekräftig? Wie hoch sind die Unsicherheiten in der Gesamtbewertung und sind unter Berücksichtigung dieser Unsicherheiten sinnvolle Aussagen möglich?

Wie ist die Relevanz einer solchen Umweltinformation zu Produkten im Kontext mit anderen Massnahmen (wie Angebotsoptimierung, Abgaben, Verbote, etc.) zu sehen?

Bei welchen Zielgruppen (Konsumentinnen und Konsumenten, Beschaffungsstellen des Handels, Zulieferer) ist eine „Umweltbepreisung" von Produkten sinnvoll?

Welches sind die Entwicklungen im nationalen und internationalen Umfeld betreffend Produktumweltinformation?

In der vorliegenden Machbarkeitsstudie wird das Grundgerüst eines Konzeptes für die ökologische Beurteilung von verschiedenen Produkten zusammengestellt. Das Konzept wird hinsichtlich der Übertragbarkeit auf unterschiedliche Produktgruppen und –sortimente und hinsichtlich einer nachfolgenden Umweltinformation vorgeschlagen. Die Arbeiten wurden in die folgenden Arbeitsschritte gegliedert:

Arbeitsschritte

- Überblick über Methoden für die Quantifizierung und die ökologische Beurteilung von Produkten
- Übersicht zu nationalen und internationalen Arbeiten
- Zieldefinition für Umweltinformationen
- Festlegung der Grenzen des zu analysierenden Systems
- Anforderungen an die Erhebung der Grundlagendaten (Sachbilanzierung)
- Auswahl einer geeigneten Umweltbewertungsmethode
- Anwendungsbeispiele
- Organisatorisches Vorgehen für die Ausarbeitung von Umweltinformation für Produkte
- Vorschläge für die Vermittlung von Umweltinformationen für Produkte

Kriterien für die Konzepterstellung

Von besonderer Wichtigkeit ist eine umfassende Umweltbewertung, die ein Bild vermittelt, das den tatsächlichen Verhältnissen entspricht („True and Fair View“). Das Konzept soll deshalb den nachfolgenden Kriterien möglichst gut entsprechen. Der Ansatz soll: Kriterien

K1 aussagekräftig sein; d.h. alle wichtigen Umweltbelastungen (Emissionen wie Energie- und Ressourcenverbrauch) über den ganzen Lebenszyklus von Produkten berücksichtigen (Vollständigkeit und Relevanz);
K2 fachlich nachvollziehbar und überprüfbar sein (Transparenz);
K3 standardisierbar, d.h. auf verschiedene Produktgruppen übertragbar sein;
K4 umsetzbar sein, d.h. mit vernünftigem Aufwand (Zeit, Kosten) auf verschiedene Produkte anwendbar sein; dazu soll sich das Konzept auch an der Datenverfügbarkeit von Hintergrunddaten und Produzentendaten orientieren, um asymmetrische Produktbeurteilungen zu vermeiden;
K5 grundsätzlich skalierbar sein, also als Basis für eine höher aggregierte Stufe nutzbar sein; d.h. als Basis für die Zusammenfassung der Umweltbelastungen von ganzen Produktsortimenten, Konsumsektoren, des Konsumverhaltens von privaten Haushalten, des Konsums eines Landes oder mehrerer Länder nutzbar sein;
K6 grundsätzlich auf andere Länder übertragbar sein; dabei wird nicht nur die technische Möglichkeit sondern auch die politische und gesellschaftliche Akzeptanz eingeschätzt;
K7 die Bewertungsergebnisse in sachlich relevante und allgemein verständliche Informationen zu Produkten transformieren;
K8 sicherstellen, dass Wertvorstellungen und politische Ziele, die bei der Umweltbewertung einfliessen, klar von wissenschaftlich basierten Bewertungsschritten unterscheidbar und in expliziter einfacher Form beschrieben werden können, so dass eine nachträgliche Gewichtung möglich ist (Trennbarkeit von Bewertungsschritten, die auf Wertvorstellungen und politischen Zielen basieren).

Ergebnisse der Studie

Die Ergebnisse der Studie werden nachfolgend anhand der Arbeitsschritte im Projekt dargestellt.

Überblick über Methoden für die Quantifizierung und die ökologische Beurteilung von Produkten

In einer ersten Auswertung werden verschiedene Methoden zur Quantifizierung und Beurteilung der Umweltbelastung von Produkten einander gegenübergestellt. Welche Methode ist geeignet?

Grundsätzlich gibt es zwei Ansätze zur Unterscheidung von Methoden: Zum einen gibt es Methoden, die über die Art der Datenerhebung definiert werden. Grundsätzlich zu unterscheiden sind physikalische Prozesskettenanalysen (Ökobilanzen (Life Cycle Assessment - LCA)), ökonomische Gesamtrechnungen (Input-Output-Analysen) und systemspezifische Stoff- bzw. Materialflussanalysen. Alle diese Methoden erlauben die Erfassung, das Modellieren und die Bewertung einer Reihe unterschiedlicher Umweltbelastungen. Zwei Ansätze von Methoden

Zum anderen gibt es Bilanzierungsmethoden, die über einen einzigen Bewertungs-Indikator definiert werden. In der Regel folgen auch diese Methoden dem Lebensweg-Ansatz einer Prozesskettenanalyse. Dazu gehören Methoden wie der ökologische Fussabdruck, die Energiebilanz und der Carbon Footprint. Letztere erlauben aber nicht eine umfassende Umweltbewertung, da nur einzelne Umweltaspekte berücksichtigt werden.

Ökobilanz als Methode

Für Umweltinformationen zu Produkten wird die Verwendung der international standardisierten Ökobilanzmethode (Life Cycle Assessment – LCA), allerdings mit einigen Abweichungen im Vergleich zur ISO 14040 (International Organization for Standardization (ISO) 2006a) empfohlen.

Übersicht zu nationalen und internationalen Arbeiten

Zur Vorbereitung der Konzepterstellung wurde eine Übersicht zu einigen bestehenden nationalen und internationalen Arbeiten angefertigt. Dabei wurden unter anderem folgende Projekte und Normen berücksichtigt:

- Environmental Product Declaration (EPD)
- ISO Normen zu Ökobilanzen und verwandten Themen
- Projet d'affichage environnemental dans le cadre de la loi Grenelle (Frankreich)
- Carbon Labels, z.B. Climatop (Schweiz), Carbon Trust (England), Tesco (England), CO_2 Label von Carrefour (Frankreich)
- "CO_2-Kennzeichnung von Waren und Dienstleistungen" (Deutschland)

Carbon footprint weit verbreitet

Die meisten der bestehenden Initiativen zur Produktkennzeichnung fokussieren auf den „Carbon Footprint“ (Bilanz der potentiellen Klimawirkung) als einzigen Indikator für die Umweltbelastung von Produkten.

Unterschiede zwischen den initiativen

In der Gegenüberstellung verschiedener Konzepte haben sich grosse Unterschiede gezeigt. Eine wichtige Unterscheidung ist die Frage, ob Nutzung und Entsorgung einbezogen werden oder ob lediglich die Umweltbelastungen bis und mit Verkaufspunkt berücksichtigt werden. Ein weiterer wichtiger Unterschied besteht im Grad der überprüfbaren und standardisierten Bilanzierungsregeln und in der Ausarbeitung von produktgruppen-spezifischen Grundsätzen, sogenannten Product Category Rules (PCR). Für einige Initiativen existieren nur wenige schriftliche Dokumentationen zur Vorgehensweise, während für andere nationale Standards ausgearbeitet wurden. Auch bezüglich der Organisationsform gibt es Unterschiede, da einige Initiativen von unabhängigen oder staatlichen Institutionen getragen werden, während andere Initiativen durch einzelne privatwirtschaftliche Akteure durchgeführt werden.

Zieldefinition für Umweltinformationen

Umweltinformation und Entscheidungsebene

Die Verringerung von Umweltbelastungen durch den Verbrauch von Produkten kann auf unterschiedlichen Entscheidungsebenen durch die Konsumierenden stattfinden. Auf der untersten Ebene werden z.B. Kaufentscheidungen über das gleiche Produkt (z.B. Vollmilch) in zwei unterschiedlichen Verpackungen verstanden. Auf der obersten Ebene stehen z.B. Kaufentscheidungen, ob Geld für Lebensmittel oder für eine Reise ausgegeben wird. Dazwischen stehen z.B. bei der Planung einer Mahlzeit Entscheidungen zwischen tierischen oder pflanzlichen Zutaten und, bei einer vegetarischen Variante, zwischen verschiedenen Gemüse- oder Getreidesorten. Den Konsumentinnen und Konsumenten steht dabei eine grosse Bandbreite von Optionen nachhaltigen Handelns offen.

Entscheidungsebenen der Konsumierenden

Die vorliegende Untersuchung zeigt die Notwendigkeit auf, ökologische Handlungshinweise über mehrere Entscheidungsebenen hinweg zu gewichten. So spielt beispielsweise die Höhe des jährlichen Fleischkonsums eine weitaus wichtigere Rolle bezüglich der Gesamtumweltbelastung eines Haushalts als die Wahl zwischen verschiedenen Verpackungsvarianten von Rindfleisch (beispielsweise Offenverkauf versus abgepackt) oder die Wahl zwischen zwei verschiedenen Sorten Rindfleisch (konventionell oder bio).

Für die Erstellung eines Konzeptes muss festgelegt werden, auf welchen Ebenen Umweltinformationen in erster Linie als Entscheidungsunterstützung dienen sollen, da es nicht möglich ist mit der gleichen Information jede Art von Entscheidung zu unterstützen. Hier wird empfohlen, zunächst Informationen für höhere Entscheidungsebenen bereitzustellen und erst nach und nach eine Differenzierung zwischen ähnlichen Produkten einzuführen. Damit kann den Konsumentinnen und Konsumenten die Grössenordnung der Umweltbelastung bei unterschiedlichen Einkaufsentscheidungen verdeutlicht werden.

Hauptziel ist, die Relevanz von verschiedenen Einkäufen aufzuzeigen

Im Gegensatz zu klassischen Ökobilanzen zum Vergleich von einzelnen Produkten mit klar definierten Rahmenbedingungen und Fragestellungen ist bei der Erfassung von Umweltinformationen für Produkte die genaue Referenz und Vergleichsgruppe nicht bekannt. Deshalb ist es deutlich schwieriger, die richtige Interpretation der Ergebnisse sicherzustellen.

Genaue Referenz nicht vorher bekannt

Festlegung der Grenzen des zu analysierenden Systems

Empfehlungen für die Systemgrenzen

Systemgrenzen definieren, welche Phasen des Lebenswegs eines Produkts in die Bilanzierung eingeschlossen werden. Die Abgrenzung der Produktionsphase (bis zum Verkaufspunkt) gegenüber der Nutzungsphase (z.B. Energieverbrauch beim Gebrauch elektrischer Apparate, Wasserverbrauch, etc.) und der Entsorgungsphase (geregelte Entsorgung, unsachgemässe Entsorgung) ist in vielen Fällen schwierig. Dazu kommt noch, dass es nicht möglich ist, allgemein gültige Richtlinien für die Berücksichtigung der Nutzung und Entsorgung zu erarbeiten, da Produkte verschiedene Nutzen haben (z.B. kann der Nutzen einer Waschmaschine durch eine 60 Grad Wäsche von 5 kg Wäsche definiert werden, und der Nutzen eines Autos durch 1 km Personentransport). Schliesslich hat das Verhalten der Konsumentinnen und Konsumenten einen wichtigen Einfluss auf die Umweltwirkungen der Nutzungs- und Entsorgungsphasen, welches stark variieren kann und deshalb schwierig vorherzusagen ist. Es gibt jedoch Produkte, bei denen genau durch diese Phasen die Hauptumweltbelastung im Lebenszyklus verursacht werden. Eine aus Umweltsicht perfekte und allgemeingültige Festlegung ist deshalb nicht möglich.

Es wird empfohlen, die Umweltbelastungen aller Produkte bis und mit Verkaufspunkt zu erfassen und auszuweisen (d.h. von der Wiege bis zum Verkaufsregal). Für diese Bilanz, sollte die Umweltbelastung pro gekaufte Einheit (z.B. pro Liter Milch, pro Joghurt oder pro Brot) gezeigt werden. Damit entspricht die Abgrenzung für den Produktpreis genau derjenigen der Umweltinformation für das Produkt. Auf diese Weise können theoretisch alle Produkte miteinander verglichen werden.

Bilanz bis zum Verkaufsort für alle Produkte

Für alle Produkte, welche verbrannt werden oder direkt in die Umwelt gelangen (z.B. Brenn- und Treibstoffe, Arzneimittel, Waschmittel, usw.) sowie für energieverbrauchende Produkte (d.h. alle Produkte, die einen Stecker oder eine Tank haben), sollen zusätzlich zu den Umweltbelastungen der Herstellung auch die Umweltbelastungen des gesamten Lebenszyklus ausgewiesen werden. Die Information zum ganzen Lebenszyklus von energieverbrauchenden Produkten muss auf Basis standardisierter Nutzungs- und Entsorgungsszenarios erfolgen (z.B. Treibstoffbedarf basierend auf einem standardisierten Fahrzyklus bei Automobilen, Strombedarf eines Standardwaschganges bei Waschmaschinen, etc.). Ferner ist es notwendig, eine funktionelle Einheit zu definieren, die den Vergleich ähnlicher Produkte erlaubt (z.B. 1 km Personentransport, oder eine 60 Grad Wäsche von 5 kg Wäsche).

Funktionelle Einheit und Nutzungsszenarios

Diese Punkte (funktionelle Einheit, standardisierte Nutzungs- und Entsorgungsszenarios) werden u.a. in spezifischen Regeln zu Produktgruppen definiert (sogenannte Product Category Rules oder PCR). PCR sollten für alle Produkte mit einem Stecker oder einem Tank entwickelt werden. Sie können die Arbeit bei der Bilanzierung erleichtern und die Vergleichbarkeit von Ergebnissen für die Nutzungsphase innerhalb von Produktgruppen erhöhen. Die PCR führen aber dazu, dass Produkte aus unterschiedlichen Gruppen nicht mehr direkt vergleichbar sind.

Produktgruppen spezifische Regeln (Product Category Rules oder PCR)

Auch bei gewissen Produkten, welche keine Energie verbrauchen oder weder verbrannt noch emittiert werden, können Nutzung oder Entsorgung einen wichtigen Einfluss auf die Gesamtumweltbelastung im Lebenszyklus haben (z.B. bei Fenstern oder Dämmungsmaterial). Es scheint bei solchen Produkten jedoch nicht immer möglich, die Nutzungsphase systematisch zu berücksichtigen. Oftmals ist unklar, was genau die Nutzungsphase dieser Produkte beinhaltet und wie der Einfluss der damit verbundenen Produkte und dem Verhalten der Konsumentinnen und Konsumenten voneinander abgegrenzt werden kann. Für solche Fälle sind umfangreiche Abklärungen und Diskussionen zwischen Experten notwendig.

Spezielle Fälle bezüglich Berücksichtigung der Nutzungsphase Produkte nicht möglich

Falls unter Berücksichtigung der genannten Schwierigkeiten eine Addition der Umweltbelastungen verschiedener Produkte zu einem Wert für z.B. bestimmte Handlungen oder eine jährliche individuelle Bilanz gewünscht wird, müssen Doppelzählungen vermieden werden. Hier wird empfohlen, für alle Produkte die Umweltbelastungen bis und mit Verkaufspunkt zu erfassen und zu zeigen (d.h. von der Wiege bis zum Verkaufsregal). Bei Produkten, die verbrannt werden oder direkt in die Umwelt gelangen, müssen auch die direkten Emissionen bei der Nutzung in der Bilanz berücksichtigt werden. In diese Gruppe fallen alle Brenn- und Treibstoffe (und damit die Verbrennungsemissionen) sowie Produkte, welche direkte Emissionen verursachen. Beispiele hierfür sind Arzneimittel und Waschmittel, Farben oder Lösungsmittel (Wasser- und Luftemissionen). Sobald aber für alle Produkte entsprechende Umweltinformationen vorliegen, können diese vom Verbraucher zu einem Wert für bestimmte Handlungen addiert werden. So können beispielsweise die Umweltausbelastungen des Waschens durch Addition der Werte für Stromlieferung, Wasserlieferung, Waschmittelherstellung und die Emissionen des Waschmittels ins Wasser während des Waschvorgangs sowie die Herstellung der Waschmaschine bestimmt werden. Auch die Entsorgung wird als eigenständige Dienstleistung angesehen; die Umweltinformation wird somit beim Kauf dieser Dienstleistung gezeigt und kann zur persönlichen Gesamtbilanz addiert werden. D.h. die Umweltinformation auf dem Kehrrichtsack, der Grünguttonne, dem Recyclingcontainer, beinhaltet auch den Abtransport und die ordnungsgemässe Behandlung wie z.B. Verbrennung oder Kompostierung.

Addition der Umweltwirkungen für Lebenszyklusbetrachtung

Anforderungen an die Erhebung der Grundlagendaten (Sachbilanzierung)

Für alle zur Diskussion stehenden Bewertungsmethoden müssen Informationen zu den Stoff- und Energieflüssen im Lebenszyklus der zu bilanzierenden Produkte zusammengetragen werden (Sachbilanz). Zum Teil können hierfür öffentlich zugängliche Datenbanken verwendet werden. Um Produkte verschiedener Hersteller oder Produktvarianten miteinander vergleichen zu können, müssen aber auch jeweils produktspezifische Daten erhoben werden, um den erforderlichen Detaillierungsgrad zu erreichen.

Datenerhebung

In der öffentlichen Diskussion wird der Sachbilanz bisher eher wenig Aufmerksamkeit geschenkt. Unterschiedliche Vorstellungen und Vorgehensweisen können jedoch die Ergebnisse von Ökobilanzen und damit auch von Umweltinformationen massgeblich beeinflussen. In den im Rahmen dieser Studie untersuchten Bilanzierungsmethoden werden hierzu teilweise abweichende Festlegungen z.B. hinsichtlich Datengrundlagen oder Allokationsverfahren (die Allokation dient dazu, die Gesamtumweltbelastung eines Produktionsprozesses auf die einzelnen Unterprodukte zu verteilen) getroffen.

ecoinvent Datenbank

Grundsätzlich wird eine Abstützung auf den ecoinvent Datenbestand v2.2 (ecoinvent Centre 2010) und die heute zugrundeliegende Methodik für die Sachbilanz (Frischknecht et al. 2007b) empfohlen. Dies stellt eine transparente und konsistente Datengrundlage sicher.

Auswahl einer geeigneten Umweltbewertungsmethode

Indikator für die Umweltbelastung

Ein wesentlicher Aspekt ist die Zusammenfassung unterschiedlicher Umweltbelastungen (wie Treibhauseffekt oder Überdüngung) zu einem Indikator. Hierzu stehen verschiedene Bewertungsmethoden zur Verfügung, die sich hinsichtlich Umfang und Vorgehen bei Charakterisierung[3] und Gewichtung[4] unterscheiden.

Verschiedene Ökobilanzbewertungsmethoden werden gemäss der am Anfang genannten Kriterien K1-K8 verglichen. Dabei werden in erster Linie Methoden berücksichtigt, die zum einen eine Vollaggregation (d.h. die Zusammenfassung aller Umweltbelastungen zu einem Indikatorwert) ermöglichen und dabei den Gewichtungsschritt klar von der naturwissenschaftlichen Modellierung trennen. Ausserdem werden nur Methoden berücksichtigt, die im Sinne von Kriterium K1 mehr als eine Umweltbelastung berücksichtigen. Berücksichtigt werden nur Methoden, die bereits häufig verwendet werden oder in der Schweiz entwickelt wurden. Folgende Umweltbewertungs-Methoden werden in der Beurteilung betrachtet:

Bewertungsmethoden

- Methode der ökologischen Knappheit - Ökofaktoren 2006 (Frischknecht et al. 2008)
- ReCiPe (Goedkoop et al. 2009) als Nachfolger von der Methode Eco-indicator 99 (H,A) (Goedkoop & Spriensma 2000)
- Impact 2002+ (Margni et al. 2003)
- Ökologischer Fussabdruck (Huijbregts et al. 2007; Wackernagel et al. 1996)
- Empfohlene Methoden der Wirkungsabschätzung des DG-JRC (Hauschild et al. 2009)

Folgende Methoden, die nur einen der wesentlichen Umweltbereiche betrachten, wurden nur grob betrachtet:

- Carbon Footprint, CO_2-Emissionen, Global Warming Potentials, etc. (nur Treibhauspotential)
- Energiebilanz, Graue Energie, Kumulierter Energieaufwand, Erdöl-Äquivalente, etc. (nur Energieverbrauch)
- Ökologischer Rucksack, Material intensity per Service Unit, etc. (nur Materialbedarf), Environmentally weighted Material Consumption.

Keine der Bewertungsmethoden erlaubt derzeit eine Bewertung aller Umweltwirkungen. Lücken bestehen z.B. bei der Bewertung von Lärm, Bodenerosion, Überfischung oder Littering. Präferenzen im Vergleich der Bewertungsmethoden hängen auch von persönlichen, politischen, bzw. gesellschaftlichen Wertvorstellungen ab und lassen sich somit nicht objektiv bestimmen.

[3] Zuordnung einzelner Schadstoffemissionen zu einem bestimmten Umweltproblem und Umrechnung in eine Standardeinheit. Z.B. Zusammenfassung der Treibhausgase CO_2, Methan und Lachgas zum Indikator Kohlendioxidäquivalente.

[4] Zusammenfassung verschiedener Umweltprobleme zu einem Indikator. Diese beruht in der Regel auch auf Werthaltungen und nicht nur auf naturwissenschaftlichen Erkenntnissen.

Es wird empfohlen, verschiedene Emissionen und Ressourcenverbräuche anhand der Methode der ökologischen Knappheit - Ökofaktoren 2006 zu gewichten. Als Indikator werden damit Umweltbelastungspunkte (UBP) berechnet.

Methode der ökologischen Knappheit 2006 und Umweltbelastungspunkte (UBP)

Diese Methode entspricht dem derzeitigen Wissensstand und spiegelt die Ziele der Schweizer Umweltpolitik am besten wider. Sie kann auch für in die Schweiz importierte Produkte verwendet werden. Zusätzlich hat sie das Potenzial, in anderen Ländern benutzt zu werden, indem nationale oder regionale Ökofaktoren bestimmt werden können, die mit den Schweizer Ökofaktoren kompatibel sind und in geographisch differenzierenden Ökobilanzen verwendet werden können. Wesentliche Weiterentwicklungsmöglichkeiten sehen wir in der Berücksichtigung von Lärm und in der Bewertung von Landumwandlungen.

Anwendungsbereich und Weiterentwicklung

Kurzfristig erscheint es nicht möglich, eine internationale Übereinkunft zu einer umfassenden Bewertungsmethode zu erreichen. Dazu sind die nationalen Zielvorstellungen aber auch Philosophien hinsichtlich qualitativer oder quantitativer Gewichtungen zu unterschiedlich. Ein Hindernis ist auch, dass die Zusammenfassung zu einem Indikator mit der Ökobilanz-Norm ISO 14040 nicht konform ist, wenn damit öffentliche Produktvergleiche durchgeführt werden. Für Gesetze und Verordnungen muss diese privatwirtschaftliche Norm hingegen nicht erfüllt werden.

Internationale Akzeptanz

Anwendungsbeispiele

Es wurde eine Auswertung der Umweltbelastungen für verschiedene Produkte durchgeführt um aufzuzeigen, wie wichtige Aspekte bei der Erarbeitung von Umweltinformationen anzugehen sind. Folgende Produkte wurden untersucht: Gemüse, Textilien, Strom, Mineralwasser und Personenwagen. Die Fallbeispiele haben illustrativen Charakter.

Fallbeispiele

Es zeigt sich, dass je nach Produkt unterschiedliche Punkte einen wesentlichen Einfluss haben können.

Beim **Gemüse** ist der landwirtschaftliche Anbau und vor allem der Einsatz von Pestiziden von besonderer Bedeutung. Hier gibt es grosse Datenunsicherheiten und Schwankungen. Vorerst müssen verlässliche Durchschnittsbilanzen erhoben werden. Eine produzentenspezifische Unterscheidung ist arbeitsintensiv und vermutlich von hoher zeitlicher und regionaler Variabilität geprägt (Stichwort witterungsabhängiger Einsatz von Pestiziden).

Gemüse

Textilien wurden bisher kaum mit Ökobilanzen untersucht. Die Herstellung erfolgt in internationaler Arbeitsteilung und oft in Ländern mit kaum verfügbaren Umweltinformationen. Die Datengrundlage muss noch deutlich verbessert werden, wozu einiger Arbeitsaufwand notwendig ist.

Textilien

Für den Vergleich verschiedener **Stromprodukte** gibt es gute Datengrundlagen. Die Wahl der Bewertungsmethode hat entscheidenden Einfluss auf die Produktvergleiche. Unterschiedliche Ergebnisse können dabei auch mit unterschiedlichen Wertvorstellungen der Methodenentwickler beziehungsweise den zugehörigen Projektbegleitgruppen erklärt werden (z.B. Gewichtung der Entsorgungsmöglichkeiten von nuklearen Abfällen).

Stromprodukte

Beim **Mineralwasser** hat sowohl die Distribution bis zum Verkaufsort wie auch die Art der Flasche einen entscheidenden Einfluss. Dies zeigt ein zusätzliches Problem für die Erstellung von Umweltinformationen zu Produkten auf. Es scheint kaum zumutbar,

Mineralwasser

dass die Bilanz am einzelnen Verkaufsort erstellt und auf dem Produkt spezifisch ausgewiesen werden kann. Wird jedoch mit Durchschnittswerten gerechnet, kann die Variabilität der Gesamtumweltbelastung so gross sein, dass z.B. Vergleiche zwischen verschiedenen Mineralwässern an konkreten Verkaufsorten nicht mehr möglich sind. Die Verwendung durchschnittlicher Distributionswege ist möglich und erlaubt eine Beurteilung der Firmenphilosophie. Sie ist aber nicht zielführend, wenn vermeintlich gering belastete Produkte dadurch verstärkt in einer grösseren Region nachgefragt würden. Deshalb müssen entsprechende Annahmen regelmässig aufdatiert werden.

Auto

Bei der Bewertung von **Fahrzeugen** spielen die Emissionen bei der Nutzung eine grosse Rolle. Mit dem Prinzip, Produkte nur bis zum Verkaufsort zu bilanzieren, sind aussagekräftige Vergleiche beim Autokauf kaum möglich. Deshalb erscheint es in diesem Fall notwendig, neben den standardisierten Umweltinformationen zur Herstellung zusätzliche Abschätzungen zu den Umweltbelastungen im Betrieb zur Verfügung zu stellen. Hierfür sind gewisse Standardisierungen z.B. hinsichtlich der Umweltbelastungen bei der Treibstoffherstellung unumgänglich.

Bei der konkreten Bewertung von Produkten wurden folgende Punkte behandelt:

Funktionelle Einheit

- Wie soll die funktionelle Einheit definiert werden?

Es wird empfohlen, die Umweltinformation immer für die Menge an verkauftem Produkt (z.B. 180 Gramm Joghurt oder 500 Gramm Joghurt) zur Verfügung zu stellen. Konsumentinnen und Konsumenten sind es gewohnt, unterschiedliche Produkte hinsichtlich deren Preise zu vergleichen, obwohl die Produkte strenggenommen nicht die gleiche Funktion erfüllen. Falls zusätzliche Informationen zur Nutzungsphase gegeben werden, ist eine sinnvolle funktionelle Einheit in einer PCR zu definieren.

Genauigkeit

- Wie soll mit ähnlichen Produkten umgegangen werden; das heisst, wo ist es legitim mit Durchschnittswerten zu rechnen? (Unterschiedliche Arten von Wassergläsern; Wasserglas vs. Weinglas). Was hat das für Auswirkungen auf die Genauigkeit der Resultate / Aussagen? Welche Trennschärfe kann mit welchem Aufwand erreicht werden?

Es wird vorgeschlagen, zunächst Durchschnittswerte für ganze Produktgruppen (wie z.B. Fleisch, Gemüse, Kosmetikprodukte, Papeterieprodukte) zu erarbeiten. Damit werden Konsumentscheidungen auf höheren Entscheidungsebenen unterstützt (z.B. Bedeutung des Fleischkonsums im Vergleich zum Gemüseeinkauf). Diese Werte können dann Schritt für Schritt für einzelne Produkte verfeinert werden. Damit ist es aber nicht möglich, einzelne ähnliche Produkte zu vergleichen.

Lebensweg

- Wann und wie kann bzw. soll die Konsum-/Nutzungsphase und Entsorgungsphase in die Bewertung eingeschlossen werden?

Die Details wurden bereits im Kapitel zu den Systemgrenzen erläutert.

Datenbasis

- Sind die benötigten Ökoinventardaten in der erforderlichen Qualität vorhanden und zugänglich? Wer muss welchen Aufwand muss zur Datenerfassung betreiben?

Für viele Konsumprodukte (z.B. Textilien, Kosmetika, Lebensmittel, Unterhaltungselektronik, etc.) gibt es noch wenig öffentlich verfügbare Sachbilanzdaten. Der Aufwand zur Erhebung erscheint sehr unterschiedlich. So ist er z.B. bei Textilien und Elektronikprodukten erheblich, da es eine Vielzahl von Produkten gibt und bisher kaum Grundlagendaten verfügbar sind. Für die Bilanz einer einzelnen Produktgruppe sind u.U. mehrere Arbeitswochen notwendig. Für andere Produkte wie Strom oder Fahrzeuge gibt es hingegen schon eine gute Datenbasis.

Prioritäre Produkte

Grundsätzlich scheint es möglich, Umweltinformationen in der vorgeschlagenen Art für alle Konsumgüter zu erarbeiten, allerdings teilweise mit erheblichem Aufwand. Prioritär sollten dabei Produktgruppen mit grosser Umweltbelastung und tatsächlichem Handlungsspielraum untersucht werden, z.B. Mobilität, Ferien, Wohnungen, Heizsysteme, Stromprodukte, Unterhaltungselektronik, Textilien, Möbel.

Vereinfachung

Für einzelne Produktgruppen erscheint es möglich, das Vorgehen zur Erarbeitung von Umweltinformationen Schritt für Schritt zu vereinfachen. Einerseits kann eine Ökobilanz helfen, zunächst die relevanten Produktionsschritte zu identifizieren. In Folgestudien werden nur noch diese detailliert untersucht. Andererseits sollte dazu Sorge getragen werden, dass Grundlagendaten auch veröffentlicht werden und so für Folgestudien zur Verfügung stehen.

Organisatorisches Vorgehen für die Ausarbeitung von Umweltinformationen für Produkte

Verantwortlichkeiten und Organisation

Neben technischen Fragen werden in der Machbarkeitsstudie auch organisatorische Aspekte angesprochen. Bezüglich der Organisationsform bestehender Initiativen gibt es viele verschiedene Ansätze. Nur in einigen kann dabei die Unabhängigkeit von Einzelinteressen gewahrt werden.

Ausarbeitung von Umweltinformation: unabhängig und transparent

Es wird empfohlen, die Ausarbeitung von Umweltinformation auf mindestens zwei unabhängige Standbeine zu stellen. Die Ausarbeitung der grundsätzlichen Bilanzregeln und die Qualitätskontrolle muss dabei unabhängig von den Interessen einzelner Hersteller oder Detailhändler erfolgen. Die Erhebung der notwendigen Daten kann durch die Produzenten, die Importeure oder jeweils in deren Auftrag erfolgen.

Eine von Herstellern und Importeuren vollständig unabhängige Datenerhebung ist kaum möglich (erschwerter oder fehlender Zugang zu den relevanten Informationen). Deshalb ist eine Validierung der Daten hinsichtlich der Bilanzierungsgrundsätze vorzusehen.

Vorschläge für die Vermittlung von Umweltinformationen für Produkte

Eine verständliche und sachlich relevante Umweltinformation für die untersuchten Produkte ist notwendig. In dieser Studie werden Vorschläge dazu ausgearbeitet, wie die Information zur Umweltbelastung von Produkten als Hilfe für Kaufentscheide von Konsumentinnen und Konsumenten dargestellt werden kann. Zu beachten ist dabei, dass Umweltinformationen in Konkurrenz zu einer Vielzahl anderer Informationen stehen. Diesbezüglich werden folgende Aspekte angesprochen:

- Darstellung der Umweltinformation zugeschnitten auf Konsumentinnen und Konsumenten und Übertragbarkeit auf andere Zielgruppen mit unterschiedlichen Bedürfnissen (Beschaffungsstellen des Handels oder der öffentlichen Hand, Zulieferer).

Die Bedürfnisse von Konsumentinnen und Konsumenten und anderen Zielgruppen sind nicht ohne weiteres vergleichbar. In diesem Bericht werden nur Umweltinformationen für Konsumentenprodukte betrachtet. Im geschäftlichen Leben ist es dagegen meist möglich, auch etwas detailliertere und produktspezifischere Informationen zu auszuweisen. Dafür kann im Prinzip die gleiche Sachbilanzmethodik und derselbe Bewertungsansatz verwendet werden.

Zielgruppen

- Wie kann die Produkt-Umweltinformation gestaltet werden, so dass die Vergleichbarkeit zwischen Produkten gewährleistet ist und es Referenzwerte für den Durchschnittskonsumierenden gibt?

Es wird empfohlen, die Bewertungsergebnisse, z.B. Umweltbelastungspunkte, mit einem Zielwert zu normalisieren und in eine allgemein bekannte Einheit umzurechnen (z.B. jährliches individuelles Budget für Konsumausgaben oder verfügbare Zeit in einem Jahr). Am geeignetsten scheint die Grösse ‚Zeit'. Ein Öko-Jahr mit 365 Öko-Tagen entspricht dabei den Zielwerten für einen umweltbewussten Konsum. Die Umrechnung kann für jede Bewertungsmethode erfolgen, für die Zielwerte bestimmt werden können. Sie kann bei methodischen Weiterentwicklungen oder verschärften Zielwerten einfach angepasst werden, ohne dass sich die für die Konsumentinnen und Konsumenten sichtbare Information grundsätzlich ändert.

Zielwert und ökologische Zeit

- Für bestimmte Produkte kann es sinnvoll sein, die Konsumentinnen und Konsumenten zusätzlich über die besten Entsorgungswege zu informieren oder ihnen aufzuzeigen, welche Auswirkungen eine unsachgemässe Entsorgung haben kann.

Entsorgung

Hierzu sollten wie bisher auch einfach verständliche Empfehlungen gegeben werden. Informationen zur Entsorgungsthematik können in Form von z.B. Broschüren ausgearbeitet werden.

Weitergehende Empfehlungen

In der Studie werden Empfehlungen auf der Grundlage des heute verfügbaren Wissens ausgearbeitet. Dabei wurden auch einige Gebiete identifiziert, bei denen weiterer Forschungsbedarf besteht.

Die öffentlich verfügbaren Datengrundlagen für Produkte, die an Konsumentinnen und Konsumenten gehen, ist relativ schwach. Bisher wurden vor allem Datengrundlagen für industrielle Grundprodukte erarbeitet. Es sollten mehr Forschungsarbeiten zur Bereitstellung von typischen Konsumprodukten (z.B. Textilien, Heimelektronik, Nahrungsmittel, etc.) gefördert werden.

Datengrundlagen für Konsumprodukte ausbauen

Schlussbemerkung

Die Bereitstellung von Umweltinformationen zu Produkten entspricht dem Wunsch vieler Konsumentinnen und Konsumenten, besser über Umweltbelastungen von Produkten informiert zu werden. Für eine umfassende Beurteilung gibt es jedoch unterschiedliche methodische, administrative und konzeptionelle Herausforderungen zu beachten. Vorerst ist es nicht möglich, alle verschiedenen Ansprüche zu erfüllen. Trotzdem können erste Schritte hin zu einer umfassenden Information gemacht werden. Zunächst müssen dabei einige Vereinfachungen in Kauf genommen werden. Dazu wurden in diesem Bericht Empfehlungen gemacht. Nun gilt es diese weiter zu entwickeln und Pilotprojekte mit konkreten Produkten durchzuführen. Die Arbeit sollte von Anfang an so geplant werden, dass Verbesserungen berücksichtigt werden können ohne dass das gesamte Konzept neu aufgegleist werden muss. Insbesondere bei Produkten, bei denen die Nutzungsphase für die Gesamtumweltbelastung wichtig ist und die Konsumentinnen und Konsumenten dafür auch einen grossen Handlungsspielraum haben ist es schwierig, nur mit vereinfachten Umweltinformationen zum Produkt umweltrelevante Verhaltensänderungen zu bewirken.

Abreviations

a	annum (year)
ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie
b2b	business-to-business
b2c	business-to-consumer
CED	Cumulative Energy Demand
CERA	Cumulative Energy Requirements Analysis
CF	Carbon Footprint
DMC	Domestic Material Consumption over GDP
DML	Decision-making level
EF	Ecological Footprint
EMC	Environmentally weighted Material Consumption
EP	eco-points
EPD	Environmental Product Declaration
EPI	Environmental Product Information
ER	Ecological Rucksack
FOEN	Swiss Federal Office for the Environment
GHG	Greenhouse Gas
GWP	Global Warming Potential
HA	Hybrid Analysis
HH	Human health
IOA	Input-Output Analysis
IOT	Input-Output Table
IPP	Integrated Product Policy
ISO	International Organization for Standardization
ME	Man-Made Environment
MFA	Material Flux Analysis
MIPS	Material Intensity per Service Unit
MM	Million
NE	Natural Environment
NGO	Non-Governmental Organisation
NR	Natural Resources
PCF	Product Carbon Footprint
PCR	Product Category Rules
WF	Water Footprint

Glossary

English	Deutsch	French	Description
Characterisation	Charakterisierung	Caractérisation	Different emissions are multiplied with substance specific characterisation factors that describe their potential contribution to the same environmental problem. Afterwards the characterised figures are summed up. The gases CO_2, CH_4, N_2O can for example all be characterised with their global warming potential, because they contribute to the same problem and it is possible to determine and compare the potential impact of the different gases.
Concept for environmental product information (CEPI)	Konzept zur Information über die Umweltbelastungen von Produkten	Concept pour l'affichage environnemental des produits	Full approach developed within this study. This covers aspects of the goal and scope definition in the LCA, guidelines for LCI modelling, the choice of the LCIA method as well as aspects going beyond the normal LCA practice for products and services such as levels of decision-making addressed with the information.
Cut-off criteria	Abschneidekriterien		Part of goal and scope definition in LCA that determines which inputs and outputs in the life cycle are excluded within the system boundaries investigated.
Damage assessment	Schadensmodellierung		The damage to human or ecosystem health is modelled from the point of emission, over diffusion in the environment and intake by the organism, to the effect caused and the related final damage.
Eco-points (EP)	Umweltbelastungspunkte (UBP)		Unit expressing the environmental impacts assessed by means of the ecological scarcity 2006 method (Frischknecht et al. 2009b).
Eco-time	Öko-Zeit		Normalization of environmental goals to a time unit in order to allow an easy understanding of environmental indicator results.
Elementary flows	Elementarflüsse		Emissions and resource uses.
Emission	Emission	Emission	Individual output of a technical process to the environment, e.g. emission of 1kg SO_2 to the air.
Environmental impacts	Umweltbelastungen	Impacts environnementaux	Quantification and description of the impacts based on the indicator result.
Environmental label	Umweltlabel	Éco-label	Voluntary information about environmental aspects provided on a product. Market-based methodology and approach.
Environmental product declaration (EPD)	Umweltdeklaration für Produkte	Déclaration environnementale de produit	A Type III environmental declaration provides quantified environmental data using predetermined parameters and, where relevant, additional environmental information (International Organization for Standardization (ISO) 2006c: 3.2).
Environmental product information (EPI)	Information über die Umweltbelastungen von Produkten	Information environnementale de produit	Phrase used in this study to describe a new approach for presenting one relevant item of environmental information for a range of products. This goes beyond EPD, which is developed for specified product groups and normally presents a range of environmental indicators.
Goal & scope	Zieldefinition	Définition de l'objectif de l'étude	Stage of LCA in which several methodological definitions are made for the specific case study.
Indicator result	Umweltindikator	Indicateur d'impact	Aggregated figure that includes different individual emissions and/or resource uses. Different LCIA methods are used to calculate the indicator value.
Interpretation	Interpretation	Interprétation	Final discussion of the analysis results.
Life cycle assessment (LCA)	Ökobilanz	Analyse de cycle de vie/écobilan	Standardized method to investigate the environmental impacts of products and services over the life cycle.
Life cycle impact assessment (LICA)	Bewertungsmethode	Évaluation des impacts de cycle de vie	Stage of LCA method assessing the environmental impacts based on results from the LCI and different stages of aggregating and weighting environmental impacts.

English	Deutsch	French	Description
Life cycle inventory analysis (LCI)	Sachbilanz	Analyse de l'inventaire de cycle de vie	Stage of LCA where data about emissions and resource uses are calculated for several stages of the life cycle and then summed up over the life cycle.
Normalisation	Normalisierung		The cumulative emission of a pollutant or the cumulative environmental impact is compared with the total emissions or impacts in a certain region.
Products	Produkte		The purchases of goods and services are summarized under one header product.
Product category rules (PCR)	Regeln für Produktkategorien		A Product Category Rule (PCR) is a set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories (International Organization for Standardization (ISO) 2006c: 3.5).
Product declaration	Produktkennzeichnung, Warendeklaration	Déclaration de produits	Mandatory information provided on products.
Standard	Norm	standard	Voluntary agreement on rules for the design of products or methodologies.
Summation	Addition		Figures for different emissions, resource uses, etc. are added up. For example, some studies add up the energy content of natural gas, crude oil, coal, etc. in order to determine the use of fossil energy carriers.
Weighting	Gewichtung		The characterised and normalised results for different environmental problems are aggregated based on a weighting principle that reflects e.g. principles of environmental policy or preferences expressed by a panel.

Inhalt

1 Introduction

1.1 Background

In a global perspective, production and consumption are steadily increasing. Private consumption is responsible for energy demand, material consumption and emissions, which cause numerous environmental impacts. Societies have to find sustainable ways of consumption that allow the social and economic development of people without exceeding planet Earth's carrying capacity.

This political aim is recognized all over the world. Integrated product policy (IPP) supports this goal in Switzerland. IPP aims to direct public and private consumption to products with high social, economic and environmental standards. The whole life cycle of the product or service must be taken into account from cradle to grave in order to support the right decisions. The Swiss Federal Office for the Environment (FOEN) has started several initiatives regarding IPP. A first study in 2006 investigated key decisions by consumers for sustainable consumption (Känzig & Jolliet 2006). A second study has been started to understand how sustainable consumption can be supported.

These studies have revealed a need to clearly quantify the environmental burdens, such as resource use and emissions, caused by individual products. Results of such an analysis should be reported in order to direct the demand of consumers or business customers to sustainable products. Environmental product information can play a major role in pursuit of this goal.

Environmental product information can be shown in different forms. Often labels are developed by private organisations on a voluntary basis. Such labelling schemes normally monitor the fulfilment of certain criteria or compare products to a reference. In contrast, environmental product information (EPI) shall be developed in a more neutral way without giving clear recommendations for one or the other product.

This projects investigates the **feasibility** of **environmental product information (EPI).** The approach taken to provide environmental information for products and services should be applicable for each individual product as well as on a regional or national level. The approach needs to take account of a full range of environmental impacts, it should cover the whole life cycle, deliver correct and transparent information and it needs to be communicated to consumers. Finally, such an approach should be introduced for several products and be accepted on a national and international level. This report investigates if and under which conditions it would be feasible to develop such a procedure for product information.

We provide here background information and recommendations that may be considered for the development of EPI.

1.2 Research questions

The Swiss Federal Office for the Environment (FOEN) asked for a study that investigates the feasibility of developing a general approach for assessing environmental impacts of goods and services and informing consumers about them. A part of the remit was that it should be possible to apply the approach to several types of products. In a first step, an approach was to be developed for final consumer products, while the environmental impact assessment method should also be applicable on a higher level of regional or national consumption. The feasibility study was also to show how results of such an impact assessment can be communicated to consumers in an easy and understandable way and which restrictions have to be considered.

The approach should be based on the methodology of life cycle assessment according to the ISO standards 14040 and 14044 (International Organization for Standardization (ISO) 2006a; b) for life cycle assessment (LCA). Other existing standards for product labelling (e.g. ISO 14020:2000 Environmental labels and declarations – general principles und ISO 14025:2006 Environmental labels and declarations – Type III environmental declarations, International Organization for Standardization (ISO) 2000) should be taken into account.

In pursuit of its main goal, the study investigates the following sub-questions:

- Which national and international activities are ongoing in the field of environmental product information based on life cycle approaches (chapter 2)? Are there relevant differences concerning the workload for data investigation (sub-chapter 2.5)?
- Which guidelines have to be developed for the inventory modelling in order to allow a fair comparison and cover all relevant aspects in the life cycle (sub-chapter 4.3)? Which background data can be used (section 4.3.5)?
- How large are uncertainties and data variations of quantitative information in view of the differentiation of several products (section 4.3.6)?
- Which impacts related to resources, ecosystem quality and human health concerns cannot be covered by the impact assessment method chosen (sub-chapter 4.4)?
- Which products can be evaluated (chapter 5)?
- Which target groups should and can be reached by the proposed approach for environmental product information (sub-chapter 6.2)?
- How effective is such an information compared to other political measures such as restrictions or subsidies (section 7.6)?

The goal of the study is not to develop a full guideline for environmental product information, but to highlight all relevant aspects that should be considered for such a development.

1.3 Criteria for the development of an approach

This project aims to develop a sound environmental product information approach. This consists of different parts which are partly based on existing methodologies and partly have to be developed specifically for the purpose of environmental product information. In order to judge the appropriateness of different possibilities the following criteria have been defined in order to compare different approaches:

K1 The approach should have high explanatory power, i.e. all key environmental impacts (emissions, and energy and resource consumption) should be taken into account across the entire life cycle of products (comprehensiveness and relevance).

K2 Results need to be reproducible and comparable (transparency).

K3 It should be possible to standardise the approach, i.e. to apply it to diverse product groups.

K4 Implementation must involve reasonable costs and working time for diverse products; to that end, the approach should be guided by the availability of background and manufacturer data, in order to avoid asymmetric product assessments.

K5 The approach should be scalable, i.e. fundamentally suited as a basis for higher levels of aggregation: the aggregate environmental impacts of entire product ranges, entire consumption sectors, the consumption behaviour of private households, the consumption of a whole country or of a group of countries.

K6 The approach should be fundamentally transferable to other countries. This is a matter not only of technical feasibility, but also of political and societal acceptance.

K7 It should be possible to transform the assessment results into technically meaningful and widely understandable product information.

K8 Value judgements and policy goals which play a role in the environmental assessment should be clearly distinguishable from scientifically grounded assessment steps. It should be possible to characterise them in an explicit and simple manner in order to allow ex-post weighting (i.e. it should be possible to separate the assessment steps which are based on value judgements and policy goals).

1.4 Reading guide

This study is structured according to the different questions tackled in this study.

In chapter 2, we introduce widely known approaches for investigating environmental impacts of products in a life cycle perspective. In chapter 3, we give an introduction to existing initiatives on the national and international level. Chapter 4 outlines important aspects of the underlying life cycle assessment for products. In sub-chapter 4.3 we investigate the guidelines for the inventory modelling. We further outline the choice of a well-suited impact assessment method for product information in sub-chapter 4.4. The proposed approach is tested with a choice of possible consumer products in chapter 5. Then we give recommendations concerning the communication of results in chapter 6. Finally recommendations from all different parts of analysis are summarised in chapter 7.

1.5 Audience of this report

This report has been produced on behalf of the Swiss Federal Office for the Environment (FOEN). In some parts, methodological issues are explained at some length in order to also inform people without an extensive background in this field. Readers who are more familiar with the methodology of life cycle assessment and similar methods, and with the impact assessment methods used in LCA, can skim across these chapters. Nevertheless, some quite technical issues concerning the provision of environmental information for products are also dealt with there.

2 Methodologies for evaluating environmental impacts from consumption

2.1 Introduction

In this chapter, we provide an overview of methodologies which can be used to evaluate the environmental impacts of consumption and consumer products. The overview is based on a former study related specifically to food consumption (Jungbluth & Frischknecht 2000) and has been revised and updated in the framework of this project. Thus it should help to understand the different concepts underlying life cycle based approaches for evaluation of environmental impacts of products.

All methodologies follow life cycle thinking. They aim to investigate environmental impacts of products and services over their full or at least parts of the life cycle. In principle, there are two overlapping descriptions of the methodologies.

The first examples are methods mainly defined by the environmental indicator investigated. Thus e.g. “carbon footprinting” considers only greenhouse gas emissions. The way in which the necessary data analysis of the life cycle is done is partly undefined and may be adapted from case to case. Thus the methodology is described more by “What is the indicator?”

On the other side, there are methodologies that have a focus on how inventory data are collected and recorded over the life cycle. The description of these types of methodologies starts with the chapter on LCA. Further methods are Hybrid Analysis and input-output-analysis. Different indicators can be derived and thus the description is more focus on “How inventory data are collected and calculated?”

With this overview, we investigate the options for applying one of the different concepts for the development of environmental product information.

2.2 Criteria for evaluating different methodologies

Different methodologies are available to evaluate the environmental impacts of consumption. They are introduced and compared in the following sub-chapters. The description of the methods is based on Jungbluth (2000). The following sections cover the criteria used to describe and evaluate each of the different methodologies.

2.2.1 Introduction

The introduction presents the principal goal of each method. It explains the intent and procedure and the technical terminology used. Information about the scientific background, the scientific community and journals used for publications complement this section.

2.2.2 Parts of life cycle, emissions investigated, indicators and aggregation principles

This section gives information about the parts of the life cycle investigated. This includes the application of specific cut-off criteria that determine the exclusion of certain inputs for the modelling of the life cycle. It outlines the emissions and resource uses that are included in the inventory. Many methods aggregate different individual emissions or resource uses to one or more indicators. The following technical terms are used in different methods for this step of aggregating different individual emissions or resource uses:

- Summation – Figures for different emissions, resource uses, etc. are added up. Some studies add up for example the energy content of natural gas, crude oil, coal, etc. in order to determine the use of fossil energy carriers.

- Characterisation – Different emissions are multiplied with substance specific characterisation factors that describe their potential contribution to the same environmental problem. Afterwards the characterised figures are summed up. The gases CO_2, CH_4, N_2O can for example all be characterised with their global warming potential, because they contribute to the same problem and it is possible to determine and compare the potential impact of the different gases.
- Damage assessment – The damage to human or ecosystem health is modelled from the point of emission, over diffusion in the environment and intake by the organism to the effect caused and the related final damage.
- Normalisation – The cumulative emission of a pollutant or the cumulative environmental impact is compared with the total emissions or impacts in a certain region.
- Weighting – The characterised and normalised results for different environmental problems are aggregated based on a weighting principle that reflects, for example, principles of environmental policy or preferences expressed by a panel.

Further terms are used in the description that are partly defined for certain methodologies. These are:

- Emission – Individual output of a technical process to the environment, e.g. emission of 1kg SO_2 to the air.
- Elementary flows – Emissions and resource uses.
- Impact assessment – Term used for different steps of aggregation in the life cycle assessment method.
- Indicator – Aggregated figure that includes different individual emissions and/or resource uses. Different methods are used to calculate the indicator value.
- Interpretation – Final discussion of the analysis results.

The indicators used and aggregation principles adopted for each of the methods are described in this section. The aggregation step presents the most decisive difference when comparing different methodologies. Subjective choices applied in the aggregation procedure determine the results of each analysis and may explain contradictory results of different case studies.

2.2.3 Data requirements and availability

Each method needs data such as statistics, energy requirements or emission factors for processes involved. This section gives a review of the data requirements and availability while investigating food products with the specific method. It also shows some differences for data availability in different countries.

2.2.4 Case studies on consumption

The section outlines the frequency of case studies with each method. One example from a case study is worked out to give an impression of each methodology. Because this section is based on an older report, focus is laid on case studies for food products. This example is neither necessarily universally valid nor up-to-date. To learn more about the underlying assumptions and uncertainties, readers interested in these results should refer to the original research work.

2.2.5 Summary of strengths and weaknesses and usefulness in policy-making

The main strengths and weaknesses of the different methods for policy-making are described in this section. This includes technical restrictions of the method and practical implementation as well as limits of the underlying assumptions and environmental indicators. This part gives also an assessment regarding the usefulness of the specific method in policy-making in the field of sustainable consumption. The environmental relevance and clarity of the indicators used are discussed.

2.3 Indicator driven methods

2.3.1 Cumulative Energy Requirements Analysis (CERA)

Introduction

Cumulative Energy Requirements Analysis (CERA) aims to investigate different energy uses over the life cycle of a given amount of a product or service. This includes the direct uses as well as the indirect or grey consumption of energy due to the use of, e.g., construction materials or pre-products.

This method has a long tradition (Boustead & Hancock 1979; Leach 1976; Pimentel 1973; Pimentel & Pimentel 1996; Singh 1986). Guidelines for cumulative energy requirements analysis have been published in Germany by VDI (1997). Papers are published in ENERGY POLICY and other journals. This type of method is also characterised as process chain analysis as it looks stage by stage at the whole process chain of a product or service.

Parts of life cycle, emissions investigated, indicators and aggregation principles

In principle, all parts of the life cycle that are related to an (direct or indirect) energy use are accounted for. The primary energy requirement, expressed in joule (or kWh), is used as an indicator. The primary energy requirement of different energy carriers, e.g., electricity, gasoline, firing wood is determined by adding the heating value of the energy carrier and the energy required for its production and delivery.

There are different approaches for determining the primary energy requirement. For CERA-calculations one may chose the lower or the upper heating value of primary energy carriers where the latter includes the evaporation energy of the vapour present in the flue gas. Furthermore, one may distinguish between energy requirements of renewable and non-renewable resources. Finally, different ways exist how to handle nuclear and renewable electricity.

Accounting for 1 kWh electricity from nuclear power, for instance, one can apply the substitution method used e.g. by BP Amoco (1999). This assumes the use of fossil fuels in a conventional thermal power plant with 33% efficiency instead of nuclear fuel (resulting in a primary energy requirement of 10.9MJ/kWh$_e$). Alternatively, one can use the average thermal efficiency of a nuclear power plant (31%, 11.5MJ/kWhe), the total primary energy requirement including production and delivery of uranium (13.3MJ/kWhe given by Frischknecht et al. 1996), or the total primary energy requirement including production, delivery and losses (about 21 MJ-eq/kWh$_e$.

An important value choice is the treatment of renewable energies. Within ecoinvent (Frischknecht et al. 2007c) and the 2000W society approach (Bébié et al. 2009), photovoltaic solar energy consumption is considered by the amount of solar energy transformed to electricity. The ETH Zurich energy strategy approach accounts for the photoelectric conversion efficiency ratio (Boulouchos et al. 2008). This assumption favours nuclear energy compared to photovoltaics.

Sometimes energy demand is converted to crude oil equivalents (litre of oil equivalents) in order to provide a more recognisable unit for communication.

Data requirements and availability

Energy, as an important economic factor, is normally well documented. Many publications provide data about the energy use of certain background processes, because cumulative energy requirements analysis has a long tradition. Thus data availability is normally not a big problem, but sometimes the databases are very old. Attention should be paid to the approach that the databases have used to aggregate different types of energy resources, which might differ considerably. Thus, it is advisable not to sum up data from different sources if it is not ensured that different energy resources have been characterised with the same method.

Case studies on consumption

Numerous case studies have examined the energy consumption attributable to food consumption (e.g. Carlsson-Kanyama & Faist 2000; Coley et al. 1997; Faist et al. 1999a; Leach 1976; Pimentel 1973; Pimentel & Pimentel 1996; Singh 1986). Cumulative energy demand was a popular approach during the first energy crises in the 1980s and 1990s. In Switzerland and Europe we see decreasing interest while the method is still quite popular in the United States.

Zamboni (1994) has investigated the energy used in the life cycle of different food products for a Swiss consumer organisation. The analysis reveals for example that the consumption of fresh peas from Switzerland needs 3.6MJ/kg while peas imported from Egypt consume 45MJ/kg due to the high energy use for air transport. Tomatoes from a Swiss greenhouse need three times more energy than those produced on open-ground.. Production of Swiss lamb meat consumes over 60MJ/kg. If it is imported by air from New Zealand, an additional 226MJ/kg are consumed due to the transport. The total energy use for 1kg lamb from New Zealand is equivalent to the energy content of 6.8 litres of fuel oil. This cumulative energy requirements analysis made it possible to provide guidance for consumers with regard to important aspects of energy use.

Summary of strengths and weaknesses and utility for policy-making

The reduction of energy consumption is one important prerequisite for sustainable development. As several environmental problems, e.g. climate change or nuclear waste disposal, are linked to energy use, this indicator can serve as a yardstick for improvement. It is also easily understandable for decision-makers such as consumers, politicians or managers of private enterprises.

Thus, the method of cumulative energy requirements analysis is useful to get a rough view on energy-related environmental impacts in a life cycle and for a comparison of individual products. For some household appliances, e.g. cooking stoves, energy use is the one important factor to evaluate the environmental impacts caused. The total energy use in a country, of specific sectors of the economy, or products is a good yardstick to measure and monitor the success of energy policy measures.

But energy use does not give a full picture of all environmental impacts in the life cycle of e.g. food or biofuel products. Thus, for example, eutrophication due to intensive animal production is one problem that is not captured by energy use in production. Furthermore, the environmental impacts vary among different energy resources. The impacts of coal use per unit energy content are normally more severe than those attributable to natural gas. Thus, cumulative energy requirements analysis cannot be the one and only method for evaluating the environmental impacts of consumption patterns.

2.3.2 **Carbon Footprint (CF)**

Introduction

Carbon footprint (CF) quantifies the emissions of greenhouse gases over the life cycle of a given amount of a product or service. This includes the direct emissions as well as the indirect or grey emissions due to the use of, e.g., construction materials or pre-products.

This method became quite popular in the last two to three years because of climate change being widely recognised as a major environmental problem at a global level. Nevertheless it has a long tradition (Biesot et al. 1995; Hofstetter 1992). Guidelines for the calculation of carbon footprints are under development. An important standard is the PAS 2050 (Carbon Trust & DEFRA 2008). The ISO 14067 standard "carbon footprint of products" is under development (International Organization for Standardization (ISO) 2009). The World Resource Institute (WRI[5]) and the World Business Council for Sustainable Development

[5] http://www.wri.org/climate

(WBCSD[6]) are presently active in the Greenhouse Gas Protocol Initiative to develop a GHG accounting framework for companies.[7] There are also ongoing initiatives to develop accounting standards for specific products, e.g. biofuels (CEN TC 383, ISO PC 248). With this range of different initiatives, general consistency is difficult to achieve.

Papers are published e.g. in CLIMATE CHANGE, INT. J. OF LCA and other journals. This type of method is also characterised as process chain analysis as it looks stage by stage at the whole process chain of a product or service.

Parts of life cycle, emissions investigated, indicators and aggregation principles

In principle, all parts of the life cycle that emit greenhouse gases are accounted for. The global warming potential (GWP), expressed in kilogram CO_2 equivalents, is used as an indicator. The GWP of different greenhouse gases, e.g., carbon dioxide, methane and dinitrogen monoxide (N_2O) is determined by characterising the emissions with factors developed by the IPCC (Solomon et al. 2007), but sometimes using former versions of this publication. Some standards or methods allow omitting parts of the life cycle, e.g. infrastructure, which leads to lower total emissions than calculated in a full assessment.

It is important to note that while they speak of CO_2 emissions most approaches take into account at least the three major greenhouse gases, while some studies really take into account only the CO_2. Furthermore it has to be noted that even if speaking about carbon footprint this method does not relate to an area but to a mass of emissions. Thus, the name could be confusing.

Several different guidelines are available, which mainly differ concerning databases, allocation rules and cut-off criteria.

Data requirements and availability

CO_2 emissions from burning fossil fuels are normally well documented. Methane and N_2O from technical processes are normally measurable. More complicated are the models for emissions of methane and N_2O from agriculture and forestry. Accounting for CO_2 emissions due to land-use changes is currently a major issue of scientific debate.

There are many publications providing data for the GWP of certain background processes, because of the long tradition (e.g. Biesot et al. 1995; ecoinvent Centre 2009; Öko-Institut 2009). Thus data availability is normally not a big problem, but sometimes the databases are very old. Attention should be paid to the modelling approach used to establish the inventories underlying the GWP indicators.

Case studies on consumption

There are many case studies of the GWP attributable to food consumption (see also sub-chapter 3.2). Most important for agricultural products are N_2O emissions due to fertiliser applications and CH_4 from animal production. Fertiliser production and direct fuel use for tractors are other important emitters in agriculture. Further important consumers in the life cycle are transportation between different stages, and the refrigeration and heating of food products during processing, retailing and consumption. The impacts on climate change due to food consumption patterns have been investigated within several LCA case studies.

Biofuels is a field that received considerable attention in recent years. Many studies calculated the GWP savings due to the use of biofuels compared to fossil fuels (e.g. Edwards et al. 2007; L-B-Systemtechnik et al. 2002). They concluded that many biofuels help to reduce climate change impacts. Advanced LCA studies showed that it is necessary to consider several environmental problems (Jungbluth et al. 2008; Zah et

[6] http://www.wbcsd.org
[7] http://www.ghgprotocol.org/

al. 2007) and thus led to the correction of political decisions based only on carbon footprints and the renewability aspect.

Summary of strengths and weaknesses and utility for policy-making

Climate change is currently seen as a major global threat to humankind. Substantial reductions of GHG emissions can only be achieved with international collaborations and agreements together with a change in thinking about the fundaments of our well-being. In order to assist this goal good knowledge about GHG emissions of different types of products is necessary.

Until now, there is a lack of consistency within the different initiatives and standards developed for the calculation of greenhouse gases.

Neglecting environmental impacts other than GHG emissions had an influence on political decisions in the past. A good example is the area of biofuels were rough assumptions of GHG savings due to biofuels together with failure to account for several other environmental aspects led to a much too positive picture of biofuels some years ago. Political decisions based on this perception are now being corrected, e.g. the European goals for biofuel share in fuel consumption.

2.3.3 **Water footprint (WF) or water backpack**

The water footprint is an approach quite similar to carbon footprint, investigating the use of fresh water resources instead of greenhouse gas emissions. So far, it is mainly used for awareness-raising, but not for direct information on products. The theme of water scarcity has attracted mounting attention in recent years.

Within the water footprint, the following parts are distinguished. Blue water stands for the use of surface water from rivers and lakes. Grey water describes the amount of polluted water released to the environment. Green water investigates the use of rainwater in production processes and agriculture.

Further information and data can be found e.g. on *www.waterfootprint.org*. We have kept this introduction short because this method was not foreseen for an in-depth evaluation. The ISO has started an initiative for a standard on “Water footprint - principles, requirements and guidance” within the framework of the ISO 140xx series on standards in the field of environmental management.

A major challenge in calculating the WF is the interpretation of the temporal and spatial dimension of water scarcity.

2.3.4 **Material Intensity per Service Unit (MIPS) or Ecological Rucksack (ER)**

Introduction

The calculation of the material intensity per service unit (MIPS) quantifies the total weight of resources extracted and materials moved due to human activities during the life cycle of a product or service. Service means the utility or function that can be obtained from a product. The ecological rucksack (ER) is the part of the material input that does not enter the product itself. The method is concerned with displaced environmental impacts, which often occur outside the consuming country. The material intensity per service unit of e.g. a package of biscuits includes the weight of its constituent materials (sugar, flour, plastic, paper, etc.) plus the weight of e.g. soil, rock, water, biomass and overburdens (re)moved during the extraction, harvesting and processing of those materials. The basic idea of this resource oriented method is that the reduction of inputs to the technosphere will also lead to reduced emissions to the environment. The method was developed at the Wuppertal-Institute, Germany (Schmidt-Bleek et. al. 1996).

Parts of life cycle, emissions investigated, indicators and aggregation principles

Different material flows are investigated from cradle to grave. Material inputs are accounted for in five separate subcategories: abiotic raw materials (minerals, fossil energy carriers, etc.), biotic raw materials (biomass), moved soil, water (fresh-, ground-, process-water), and air (oxygen for combustion processes).

It is assumed that the reduction of input flow is generally associated with reduced wastes and emissions. There is no specific procedure to characterise the environmental relevance of the different types of material flows. Different mineral resources, for example, are added up without taking into account their scarcity. Emissions are not accounted for.

A key indicator used in ER analysis is the total material consumption (TMC) per capita. It describes the per capita material flows caused by economic activities of a given region, within and beyond that region.

Data requirements and availability

There is no published background database which could be used for own analyses. Most of the case studies are based on information from the Wuppertal-Institute in Germany. It is difficult to assess the data availability in other countries.[8]

Case studies on consumption

Loske & Bleischwitz (1996) investigated the material intensities due to food consumption in Germany. They calculated the intensities for different product groups such as milk, vegetables, etc.. Meat products show the highest intensities (>17 kg of masses moved per kg product) followed by sugar and fats. Vegetable, fruits, fish and pulps show relatively low intensities (< 2 kg/kg). Food consumption has a share of about 20% for the TMC of households.

Table 2.1 shows a calculation of MIPS due to food consumption in Switzerland based on data investigated for Germany (Jungbluth 2000:52; Loske & Bleischwitz 1996:104). Meat, milk and sugar are the most important product groups with regard to the masses moved.

[8] A report on "Modelling a Socially and Environmentally Sustainable European Union" with some calculations valid for Europe can be found on *http://www.wupperinst.org/Projekte/SuE/HTMLtexts/Pages/finalrep.html*.

Tab. 2.1 Material intensity for different groups of food products consumed in Switzerland in 1995 (Jungbluth 2000:52; Loske & Bleischwitz 1996:104).

Product Group	Food consumption (kg) per capita	MIPS (kg/kg)	MIPS (kg/year/capita)	Share of product group for total MIPS of food consumption
Milk	148.7	6.6	981	27.5%
Vegetables	89.1	1.4	125	3.5%
Grain	74.8	3.7	277	7.8%
Meat	57.6	16.7	962	26.9%
Vegetables	99.2	1.4	139	3.9%
Potatoes	46.6	2.0	93	2.6%
Sugar	46.8	13.1	613	17.2%
Vegetable oils and fats	13.5	12.1	163	4.6%
Eggs	10.2	4.2	43	1.2%
Fish, etc.	7.5	1.3	10	0.3%
Animal fats and oils	8.5	16.7	142	4.0%
Legumes	11.2	2.0	22	0.6%
Total food consumption	613.7	5.8	3570	100%

Summary of strengths and weaknesses and utility for policy-making

Ecological rucksacks take a technical standpoint, focusing on the need to monitor and reduce the volume of material flows by means of eco-efficiency measures (particularly dematerialisation and materials reuse) and lifestyle change (OECD 1997). The method gives an insight into the masses moved due to today's consumption patterns. This helps raise awareness of the need for lifestyle changes, as mass is an easily understandable indicator. The MIPS indicator, which aggregates mass and energy, can also be used as a proxy measure representing environmental impacts if the decision-makers accept the underlying assumptions.

The aggregation of different kinds of resource uses and material flows without a weighting of their environmental relevance is a weak point. Only inputs from nature but no outputs are considered. The method provides a clear result independent of the value judgement of the decision-makers and stakeholders due to the prescribed weighting procedure that cannot be modified by the decision-maker. Only looking at the weight of material used might not be appropriate for the discussion of environmental impacts (such as toxicity or biodiversity) in detail. There are only few case studies from other organisations than the Wuppertal-Institute due to the limited availability of a common database.

2.3.5 **Ecological Footprint (EF)**

Introduction

The ecological footprint (EF) concept is a measure to estimate people's impact on the ecosphere and to check if the load attributable to of these people's consumption patterns (be it a household, city, nation or humankind in its entirety) stays within the ecological carrying capacity of Earth's biosphere, or the carrying capacity of the particular region. The EF assesses how much biologically productive area people use today to maintain their consumption (Wackernagel et al. 2000b).

The calculation of the ecological footprint is based on the assumption that most of the resources consumed and wastes generated can be traced back to the consumption of goods and services (Wackernagel et al. 2000b). The ecological footprint of a defined population (e.g. a single individual, a whole city, or a country) is expressed as the area of biologically productive land that is used exclusively to produce all resources consumed and to assimilate all wastes generated by that population. These areas are summed up along the life cycle of a product or service (for a more detailed description see Wackernagel et al. 1996).

The Global Footprint Network has developed a standard that describes methodological aspects for calculating environmental footprints on a global or national level as well as for single products or services (Global Footprint Network 2009).

Methodological discussions on the EF concept can be followed in an email group.[9] Excerpts from the ongoing debate about the pros and cons of this concept were published in a special issue of ECOLOGICAL ECONOMICS 32 (2000).

Parts of life cycle, emissions investigated, indicators and aggregation principles

The investigation looks at all parts of the life cycle of the products and services consumed in a certain region and accounts for land uses, resource consumption and emissions of pollutants. The EF of CO_2 emissions is for example converted to a land use by quantifying the productive land that is necessary to assimilate the emitted CO_2. All other greenhouse gasses, such as methane or N_2O, are not taken into account. Until 2008, the method also included a rough assumption for the use of nuclear energy that was converted with the same factor as fossil electricity.

Only resources that can be regenerated within given limits and wastes that can be absorbed by the biosphere at sufficiently low levels are accounted for. All activities that are systematically in contradiction with sustainability are not considered in the calculations, because Wackernagel *et al.* (2000a) assume that for a sustainable world, their use or emissions needs to be phased out. There is, for example, no sustainable regenerative rate for heavy metals, persistent organic and inorganic toxics, radioactive materials, or biohazardous waste.

Data requirements and availability

There are no specific databases available that can be used in order to calculate the EF for a given food product. But there are case studies for different countries and for a range of food products consumed by households (e.g. Wackernagel et al. 2000a; Wackernagel et al. 2000b). EF can also be calculated as an indicator with LCA data (Huijbregts et al. 2007). The calculations for nations are mainly based on statistical data for e.g. energy use, consumption and productive land available.

Case studies on consumption

Normally footprint studies do not investigate individual products, but the carrying capacity of a whole region. Food consumption is one of the activities integrated in EF assessments. WADA (1993) investigated tomato production in British Columbia. The ecological footprint of tomatoes from greenhouse is 10 to 20 times higher than the one of open-air production even though the direct land use of the greenhouse is smaller (cited in Wackernagel et al. 1996). WACKERNAGEL *et al.* (2000a) have developed tools to analyse household consumption in different countries and to estimate the footprint of different nations. These tools include data sets covering groups of food products such as bread, rice, vegetables, meat, etc..[10]

Table 2.2 shows an own calculation for the ecological footprint attributable to average Swiss food consumption patterns in 1997 with an Excel tool provided by Wackernagel et al. (Schweizerischer Bauernverband 1999; Wackernagel et al. 2000a). The table shows the direct and indirect land uses. These land uses are aggregated using primary biomass equivalency factors that represent the relative capacity of different types of land (land in different regions) to produce biomass. In addition, the equivalency factors are scaled by a factor that ensures that the sum for all regions is equal to the global capacity or the globally available land. The total footprint due to food consumption is calculated with the tool to be 22’902 m2 per Swiss capita, which is shown in the last row (Schweizerischer Bauernverband 1999; Wackernagel et al. 2000a). The total ecological footprint of a Swiss citizen considering the consumption of all goods is calculated by Wackernagel et al. (2000b) to be 66'000 m2 while the existing ecological capacity (the productive land in

[9] See *http://www.egroups.com/group/ecofootprints/*.
[10] A list of case studies can also be found on *http://www.bestfootforward.com/*.

Switzerland divided through the Swiss population) is only 23'000 m2 (both expressed in area with world average productivity).

Table 2.2 Calculation for the ecological footprint in square metres per capita attributable to Swiss food consumption in 1997 (Schweizerischer Bauernverband 1999; Wackernagel et al. 2000a).

CATEGORIES	Units	AMOUNT per year	I) FOSSIL ENERGY	II) ARABLE LAND	III) PASTURE	IV) FOREST	V) BUILT-U LAND	VI) SEA
1.-FOOD								
.Veggies, potatoes & fruit	[kg]	242.0	375	254				
.Bread	[kg]	11.7	45	33				
.Rice, cereals, noodles, etc.	[kg]	75.7	235	287				
.Beans	[kg]	0.0	0	0				
.Milk & yogurt	[l]	116.1	180		2'795			
.Ice cream, sour cream	[l]	9.2	53		1'107			
.Cheese, butter	[kg]	21.8	220		5'247			
.Eggs [assumed to be 50 g each]	[number]	276.0	53	175				
.Meat								
..Pork	[kg]	23.6	366	205				
..Chicken, turkey	[kg]	10.7	133	110				
..Beef (grain fed)	[kg]	3.5	70	148	842			
..Beef (pasture fed)	[kg]	12.4	250		4'263			
.Fish	[kg]	7.4	172					3'721
.Juice & wine	[l]	98.6	382	244				
.Sugar	[kg]	44.7	111	87				
.Vegetable oil & fat								
..solid	[kg]	21.6	97	617				
..liquid	[l]	0.0	0	0				
.Tea & coffee	[kg]	8.7	101	164				
.Garden [area used for food]	[m2]	0.0		0				
.Eating out [complete meals]	[number]	0.0	0	0	0			
SUB-TOTAL-1			**2'843**	**2'323**	**14'254**	**0**	**0**	**3'721**

CATEGORIES	I) FOSSIL ENERGY LD.	II) ARABLE LAND	III) PASTURE	IV) FOREST	V) BUILT-UP LAND	VI) SEA	TOTAL
1.-FOOD	5'390	6'754	9'555	0	0	1'203	**22'902**

Summary of strengths and weaknesses and utility for policy-making

The ecological footprint is an awareness-raising tool that helps to emphasise the necessity for sustainable development. It was developed to assess to what extent the human economy is overshooting the ecological capacity of planet Earth. Calculations for certain areas, e.g. cities, show that the area of land available cannot sustainable fulfil the requirements of current consumption patterns. The method's main strength is the easy communication of results and the clarity of the indicator that accounts for the whole life cycle. The method thus gives a yardstick for the sustainability of lifestyles and it can be used as a proxy indicator if the decision-makers accept the underlying assumptions. The method might help, for example, to assess the sustainability of trade in particular goods or services. In foreign policy, the approach could influence aid and trade agreements or help to inform future international debates about sustainable lifestyles (OECD 1997).

In order to reach this goal many simplifications are necessary. Emissions of toxic substances, such as heavy metals, are not covered by the EF because it is assumed that these substances are accumulated and not biodegradable. In addition, all other air pollutants than CO_2 and all emissions to water and soil are not covered by the method. The method was not initially developed for a detailed comparison of individual products, but now it is used for it sometimes.

2.3.6 **Transport related methods**

Introduction

Transports related to food products are known to contribute to certain environmental problems such as primary energy consumption, CO_2 emissions or noise. Freight transports increased due to globalisation and economic optimisation of production processes. They have been an issue of political debate. Calls for regionalism are one of the answers to address traffic related environmental problems.

Different methods aim to analyse the transports due to the production of mainly food products. BÖGE (1995) investigated for example the total of kilometres that the different ingredients of a strawberry yoghurt travelled until the product reaches the shopping basket of the consumer. CARLSSON (1997) proposed a method to calculate a weighted average source point or distance (WASP/WASD) for the origin of products consumed in one country. But until now there is no common way to investigate transport related environmental impacts.

Parts of life cycle, emissions investigated, indicators and aggregation principles

All transports of the product and pre-products are investigated by BÖGE (1995) while CARLSSON (1997) accounts for the transport from producer to consumer for both Swedish produced and imported products. The total kilometres travelled or the tonne-kilometres for a certain product or consumption pattern serve as indicators. Environmental impacts of the transport modes are not quantified so far.

Data requirements and availability

Even with the limited scope, data are not easy to come by. Normally, producers of a product only know the origin of the pre-products they buy directly, but they know little about the transports that took place before. It is difficult to estimate average figures for a product as it may reach the consumer by different paths.

Case studies on consumption

The method is mainly known for food products (Böge 1995; Carlsson 1997). The case studies show that even simple products such as yoghurt are associated with many transport processes taking place in the background due to the delivery of numerous ingredients, packaging materials, etc. to the manufacturer (Böge 1995).

Carlsson-Kanyama (1999) investigated transports due to Swedish consumption patterns of carrots and tomatoes in detail. The average distances (WASD) from the producer to the consumer of carrots and tomatoes were 320km and 1340km, respectively. An analysis for the time span 1965 to 1992 reveals a movement of the WASP of grapes from northern Algeria to Mauritania. The method does not only allow to calculate the point of origin, but also to estimate the average point of food consumption. For Sweden, this has been located at 59° 2’ N and 15° 11’ E, close to a town called Svennevad (Carlsson-Kanyama 1999:14-15).

Summary of strengths and weaknesses and utility for policy-making

The investigation of transports related to a certain product is interesting information. Calculation of WASD and WASP allows a direct comparison of consumption patterns and their development. The investigation of transport kilometres is valuable when related to a clear analytical perspective on transport related environmental impacts. The method informs about some of the impacts associated with globalisation.

A weak point of this type of analysis is that environmental impacts of different modes of transportation vary considerably. Thus, e.g. a tonne-kilometre travelled by ship has much lower environmental impacts than a tonne-kilometre delivered by an airplane.

A detailed comparison of regional products with products from a global production scheme in an LCA shows that the regional products are not less polluting in every case. This is due to different production conditions and the disparate effects of different modes of transportation. The investigation shows that the environmental impacts of food products should be investigated over the full life cycle (e.g. Mila i Canals et al. 2007; Probst 1998; Stadig 1998). A discussion in the public with only a focus on transports might lead to a biased picture as in some cases transports might reduce the environmental impacts of a product if e.g. this prevents heated greenhouse production.

2.4 Inventory driven methods

2.4.1 Life Cycle Assessment (LCA)

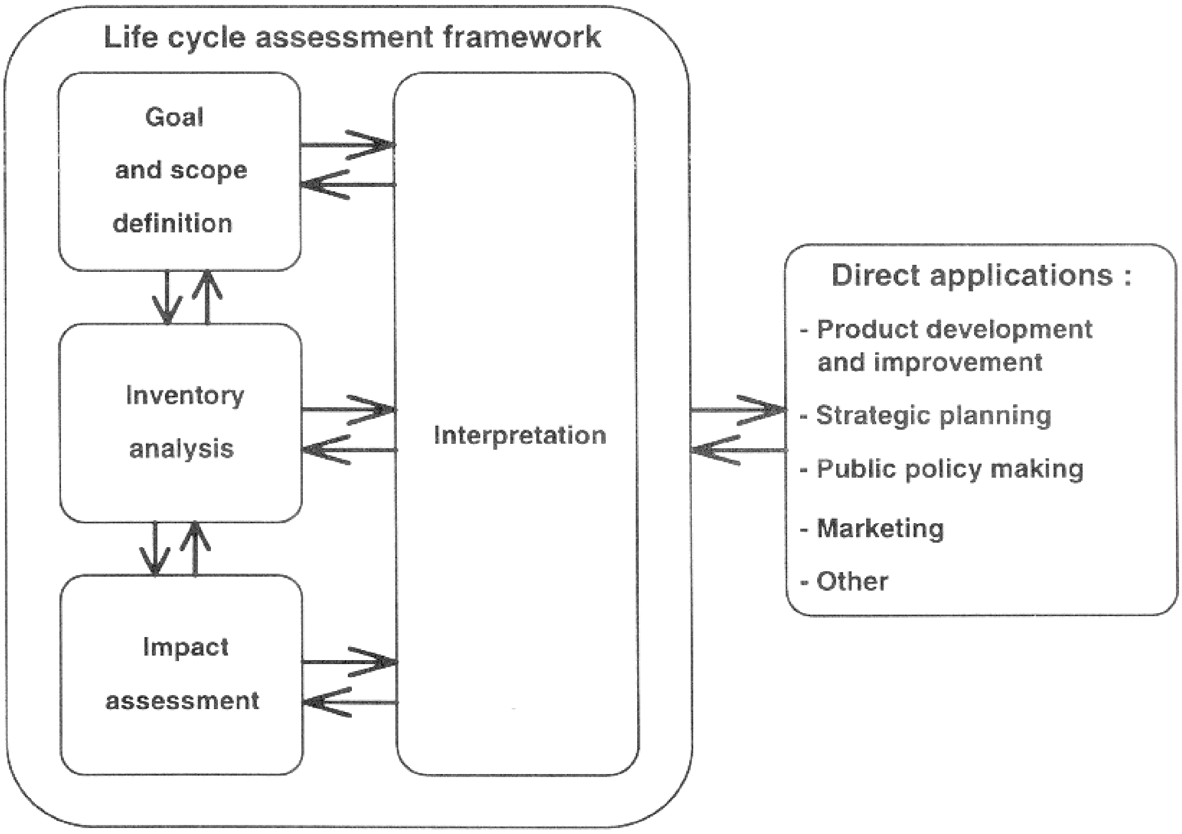
Introduction

The method of life cycle assessment (LCA) (some authors use the older term life cycle analysis or ecobalance, the latter is derived from the German "Ökobilanz") aims to investigate and compare environmental impacts of products or services that occur from cradle to grave. This means that the whole life cycle from resource extraction to final waste treatment is investigated.

The method has been developed starting from cumulative energy requirements analysis and including more and more emissions of pollutants and consumption of resources. The International Organization for Standardization (ISO) (2006a; 2006b) standardises the basic principles. LCA is used for hot spot analysis, product or process improvement and for making comparative assertions, marketing and environmental policy.

The method distinguishes four main phases, namely (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation (see Fig 2.1). The "Goal and scope definition" describes the underlying questions, the target audience, the system boundaries and the definition of a functional unit used in the comparison of different alternatives. The inputs of resources, materials and energy as well as outputs of products and emissions are investigated and recorded in the "Life cycle inventory analysis". Its result is a list of resources consumed and pollutants emitted. These elementary flows (emissions and resource consumptions) are described, characterised and aggregated during the "Impact assessment". Conclusions are drawn during the "Interpretation" phase. The different phases of an LCA are not necessarily executed in a step by step procedure, and they can be refined in an iterative manner throughout the study.

Fig. 2.1 Phases of an LCA (International Organization for Standardization (ISO) 2006a)



The ISO standards are not mandatory for conducting LCA studies. However, it is strongly recommendable to follow the guidelines of the ISO standards as far as possible for LCA studies disclosed to the public in order to increase their credibility. This is especially important for comparative assertions that are disclosed to the public.

The Society of Environmental Toxicology and Chemistry (SETAC)[11] hosts the scientific community. Papers on LCA methods and case studies are published by the INTERNATIONAL JOURNAL OF LCA, the JOURNAL FOR CLEANER PRODUCTION, the JOURNAL OF INDUSTRIAL ECOLOGY, ENVIRONMENTAL SCIENCE AND TECHNOLOGY and the ENVIRONMENTAL IMPACT ASSESSMENT REVIEW.

Parts of life cycle, emissions investigated, indicators and aggregation principles

The method quantifies the environmental impacts of the full life cycle of a product from cradle to grave including the life cycle of all pre-products and energy carriers used. All types of environmental interventions, e.g. emissions into water, air and soil as well as resource uses (primary energy carrier, land, etc.) are accounted for. Some authors include additional effects, e.g. the direct health impacts on employees in the production facilities.

An intermediate result of an LCA is an inventory table with data about the emission of hundreds of individual substances and many resource uses. Impact assessment methods for the aggregation of these results are proposed for example by (Frischknecht et al. 2009b; Goedkoop & Spriensma 2000; Goedkoop et al. 2009; Guinée et al. 2001; Hauschild & Wenzel 1997; Huijbregts 1999; Kramer et al. 1999; Steen 1999). These methods consist of standardised procedures for one or more of the following steps (introduced in sub-chapter 2.2):

- Characterisation or damage assessment
- Normalisation
- Weighting

The impact assessment method is usually chosen with regard to pollutants emitted in the life cycle (e.g. agricultural chemicals), the region under study (e.g. Europe) and the decision-maker addressed. Often the studies use different impact assessment methods simultaneously in order to see and discuss differences in the outcome.

Data requirements and availability

Normally, data investigation is the most time consuming step of an LCA. In the last years, the situation has been continuously improved due to the creation of standardised background databases (e.g. ecoinvent Centre 2009) and LCA software products that include these background data (e.g. PRé Consultants 2009).

Case studies on consumption

Packaging materials were one of the first areas in which LCA studies were applied (e.g. Habersatter et al. 1998; Hunt 1974; Schmitz et al. 1995). Since then several thousands of LCA case studies have been conducted on all types of consumer products.

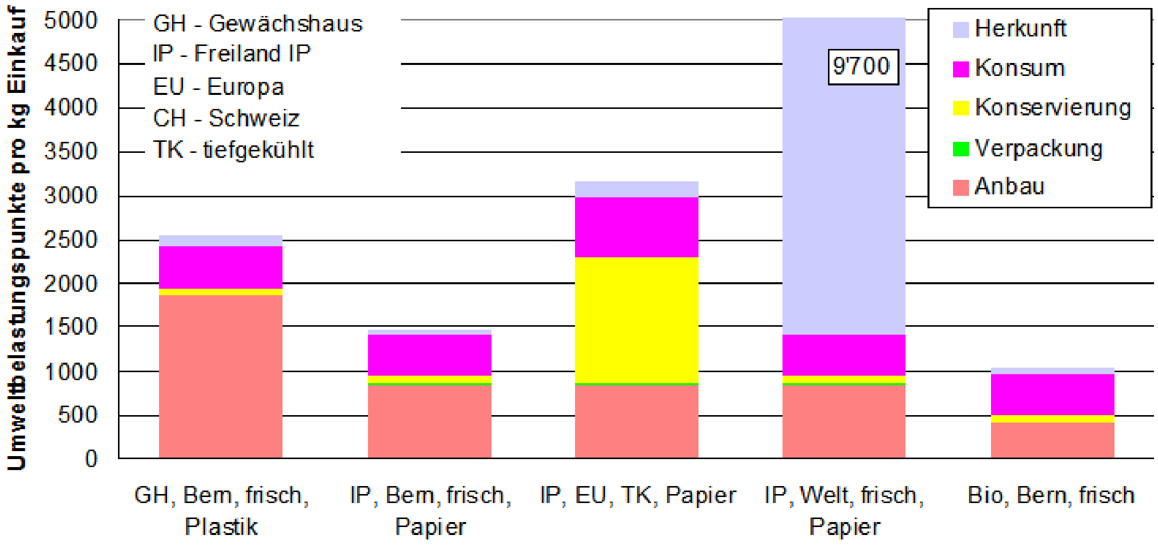
The environmental consequences of vegetable purchases[12] have been investigated by Jungbluth et al. (2000). Fig 2.2 shows a result using the ecological scarcity impact assessment method (Frischknecht et al. 2009b). Different characteristics (agricultural production technique, conservation type, origin, packaging and consumption) might be important for the overall impacts of a vegetable product. A vegetable flown in

[11] See *www.ecomed.de/journals/lca/welcome.htm* and *www.setac.org*.

[12] An average environmental impact has been calculated for vegetables from organic, integrated and greenhouse production based on specific single LCAs for about ten products each. The results cannot be generalized as a general environmental advantage for products from integrated production in comparison to organic products, due to the necessary assumptions for the calculation of the average and uncertainties of the impact assessment method.

from overseas has the highest impact. All stages of the life cycle might be important with respect to the environmental impacts depending on the type of product investigated. The most important possibilities for consumers to reduce the environmental impacts of their vegetable purchases are to abstain from products flown in from overseas or produced in greenhouses. The study of Jungbluth (2000) also shows the relevance of different pollutants such as nitrate, phosphate, pesticides and heavy metals not directly linked to energy use. A detailed discussion of the results for single parts of the life cycle can be found in Jungbluth (2000).

Fig. 2.2 Environmental impacts of vegetable purchases with different characteristics investigated in a modular LCA and weighted with the Ecological Scarcity method (Frischknecht et al. 2009b; Jungbluth et al. 2010a).



Summary of strengths and weaknesses and utility for policy-making

Main strengths of this method are the holistic approach and the structured procedure for goal definition, data handling and impact assessment. The method considers more environmental impacts than all other methods. It fits best for the detailed comparison of products with completely different environmental impacts in the life cycle (e.g. imported vegetable from open-air against a regional greenhouse product).

LCA is especially useful to identify hot spots with regard to the environmental impacts in the life cycle of consumer products and thus to prioritise and assist policy measures in product policy. In addition, it can be used to differentiate the impacts due to consumer decisions while purchasing certain products.

The main weaknesses are the time consuming acquisition of data and the expectation that LCA tells the truth about all environmental impacts. The application of LCA for decision-making is restricted due to the specific object and the initial assumptions for an individual case study. It is still not possible to quantify all known environmental impacts, e.g. noise. Additional information is necessary for decision-making in some cases.

A strength, but also a weakness is the flexibility while using different methods to aggregate emissions and resource uses to indicators. On the one hand, prevailing differences between impact assessment methods might lead to opposite results of an LCA investigating the same question, but on the other side the flexibility allows to choose the impact assessment method most appropriate for the given question and the decision-maker's needs.

2.4.2 Input-Output Analysis (IOA)

Introduction

Input-output analysis describes and analyses the structure of an economy in terms of the interdependence among its different sectors. This description uses monetary units and can be extended to other flows, e.g. of energy resources or environmental pollutants (IOEA: input-output energy analysis). As a result the direct and indirect emissions of each economic sector such as agriculture, chemical industry or catering, can be calculated and expressed as an environmental impact per economic value also known as total **energy (or environmental) intensity** of the different sectors.

An input-output model provides a framework for tracking the payments made by industries to other industries, and by consumers to industries, in the production of commodities and services. Table 2.3 shows a fictitious example for the transaction matrix. One can read from this example that the energy sector consumes energy and materials each for 10CHF in order to produce a total of 40CHF. From this production, products equal to a value of 20CHF are supplied to the final demand.

The economist Wassily LEONTIEF (1936) developed a method of inverting the economic transaction matrix so that the effect of any given set of consumer purchases on industry expenditures throughout the economy can be calculated (Chevrot 2000). The economic method can be extended in different ways in order to investigate the environmental impacts caused by different economic sectors.

In a first step the direct emissions or energy uses of each sector are investigated and inserted into the input-output table. The energy sector uses 80MJ of primary energy per year in our example (as shown in the second last row of our example), while the material sector does not use energy resources (e.g. crude oil or hard coal) directly. This sector consumes energy indirectly by purchasing products, for example gasoline or electricity, from the energy sector.

The question to be answered is now: How much energy is used indirectly by the material sector due to the consumption of products from the energy sector? The matrix with the economic and environmental flows can be inverted in a mathematical operation. This results finally in a figure for the energy intensity of final demand. For the example in Table 2.3 this results in 3.2MJ/CHF and 1.6MJ/CHF that is used to produce goods (energy and material, respectively) for the final demand (products consumed by consumers). The total indirect energy demand of each sector can be calculated as shown in the last column.

Tab. 2.3 Example for a simple Input-Output Analysis in a fictitious economy. The input-output table is shown in the bold frame in the upper left part. Extensions for the IOEA are in *italics* (Wilting 1996:31).

		energy	materials	final demand	total	*energy intensity of final demand*	*indirect energy use to meet the final demand*
		CHF	CHF	CHF	CHF	*MJ/CHF*	*MJ*
energy	CHF	10	10	20	40	*3.2*	*64*
materials	CHF	10	0	10	20	*1.6*	*16*
primary inputs	CHF	20	10	-	30		
total	CHF	40	20	30	-		
direct energy use	*MJ*	*80*	*0*				
direct energy intensity	*MJ/ CHF*	*2*	*0*				

The calculated energy (or environmental) intensity can be used in a following step to calculate the impacts of certain consumption patterns and the share of different "need fields" (or "consumption clusters"; German: *Bedürfnisfelder*). While knowing the expenditures for commodities from different economic sectors (e.g. food, transport, etc.), these monetary flows can be multiplied with the intensities and summed up.

Input-output research is published in journals dealing with political economy and cumulative energy requirements analysis.

Parts of life cycle, emissions investigated, indicators and aggregation principles

The method includes all parts of the life cycle that cause monetary flows, e.g. fertiliser production, transport, as well as spending for taxes, services, or office materials, which are often neglected by the process-chain based methods. The IOA does not cover impacts of processes without an economic flow, e.g. the composting of wastes in one's own garden. The kind of pollutants that can be covered by the method depends mainly on the availability of statistical data about total direct emissions of all sectors in the economy.

Emissions of certain substances, e.g. CO_2, or energy use are often used as indicators. In countries with a good database for emissions in different economic sectors, e.g. the USA, it is even possible to cover additional pollutants. Sometimes different emissions related to one environmental problem are aggregated by using characterisation factors, e.g. the global warming potential for greenhouse gases.

Data requirements and availability

The method needs good general and environmental accounting data for the IO table and the linkages between economic activity and environmental impacts. The more sectors are distinguished in the input-output table, the more accurate environmental analyses are possible. The time spent on an analysis is substantial at the beginning. In some cases, e.g. for the USA, it is possible to cover a range of different emissions while in other countries, e.g. Switzerland, it is so far even difficult to trace just energy use.

Many IOA studies rely on the detailed IOT table from the US. The last economic IOT for Switzerland covered the year 2001 (Nathani et al. 2008). Preliminary data are available in the same classification for greenhouse gases (Sutter et al. 2009). An environmental IOA has not yet been developed.[13]

Case studies on consumption

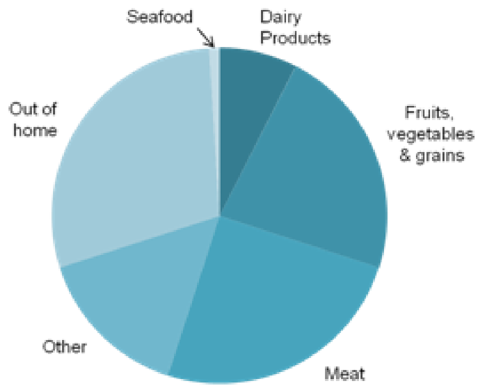
A recent study investigated the environmental impacts of consumption in Europe (Tukker et al. 2006). Details of this study are summarised in section 3.2.2.

A case study about food consumption in the USA with an Input-Output Analysis is described by CHEVROT (2000). Other known case studies investigated overall household consumption or energy use in different sectors of one country. They calculated the share of food consumption patterns to be 15% to 20% of the total impacts caused by household consumption (Knoepfel 1995; Norris 1998; Weber et al. 1996a; Weber et al. 1996b; Wilting 1996).

The Union of Concerned Scientists has investigated the annual emissions of greenhouse gases (tons of carbons of CO2, methane, and nitrous oxide) from production through consumption in the USA with an IOA (Brower & Leon 1999; cited in Kauffman & Chevrot 2000). Fig 2.3 shows that the combined consumption of meat, fruits and vegetables contributes most to greenhouse gas emissions from household food consumption patterns. However, the trend towards eating away from home (which involves factoring and transportation to and from food service establishments) is also a significant contributor to GHG emissions (Brower & Leon 1999; cited in Kauffman & Chevrot 2000:21).

[13] A project quotation for the first establishment of an environmental IOT was submitted by ESU-services and Rütter + Partner to the FOEN in 2009.

Fig. 2.3 Greenhouse gas emissions of different sub-sectors due to food consumption investigated with an input output analysis for the USA (Brower & Leon 1999).



Summary of strengths and weaknesses and utility for policy-making

The method is valuable to investigate the energy use (or some environmental impacts) of average total consumption patterns in an economy, as it is easily possible to calculate the energy requirements (environmental impacts) for average consumer goods. The method is useful to assess the share of different economic sectors or household activities in total energy use or emissions of certain pollutants. It is also applicable in scenario assessments that model the impacts of potential policy measures.

By using monetary flows, IOA enables to generalise data that would otherwise be difficult to compare. Using monetary flows renders the analysis more comprehensive as well as easily comparable across years. A specific problem of IOA modelling is the linkage to other IOA for imported goods (see e.g. Ahmad & Wyckoff 2003; Hertwich & Peters 2009). This is especially important in the case of Switzerland with a high share of imported products (Jungbluth et al. 2007c).

Normally the method is not exact enough to calculate and compare the environmental impacts of individual products of an economic sector due to the high level of aggregation. The applicability of IOA strongly depends on the availability of economic and environmental data about the economy in a given country including its trade with other countries. Thus there is a high initial effort to establish a database. In most countries, it is not possible to cover all environmental important problems of consumption such as eutrophication, pesticide or water use. It is difficult to use the results of an IOA to calculate the environmental impacts of individual consumer products.

2.4.3 Hybrid Analysis (HA)

Introduction

Hybrid Analysis (HA) quantifies the energy (or CO_2, etc.) intensities of products in a **simplified manner**. It combines information from the Input-Output Analysis and a process chain analysis in order to calculate the energy requirement over the life cycle of a product or service in relation to the average consumer price. These intensities can be linked with statistical information on household expenditures for a range of individual products in order to analyse different consumption patterns in more detail than with the Input-Output Analysis that investigates the energy intensities only for whole sectors of an economy.

An investigation of major energy uses within the life cycle is supplemented with information about further energy inputs from the input-output table. To give an example for tomatoes: The energy use due to the use of fertilisers and fuels for machinery is accounted for directly by investigating the amount used. The remaining other energy use, e.g. for the construction of farm buildings, is calculated with the energy intensity of the respective economic sector (i.e. construction services) and the spending of farmers for these items.

The method has been developed in the Netherlands (van Engelenburg et al. 1994) and all types of consumer products have been investigated (Biesot et al. 1995; Kramer & Moll 1995). The workload of this project was considerable with several researchers and research institutions involved over several years. Some case studies are known from other countries (Weber et al. 1996a; Weber et al. 1996b; Zaccheddu 1997).

Parts of life cycle, emissions investigated, indicators and aggregation principles

All parts of the life cycle, including the expenditures for taxes, services, etc., are investigated. The detail of investigation depends on the information available and the required precision. Besides the energy requirement, some studies investigate also emissions of air pollutants due to the combustion of energy carriers (Weber et al. 1996a; Weber et al. 1996b) or include the direct emissions of greenhouse gases during food production (Kramer et al. 1999).

Indicators are the use of primary non-renewable energy resources and pollutants such as CO_2, NO_x or SO_2. The level of detail depends on the availability of data in input-output tables. So far, there is no aggregation of different pollutants besides the calculation of the global warming potential, but in principle this would be possible as well.

Data requirements and availability

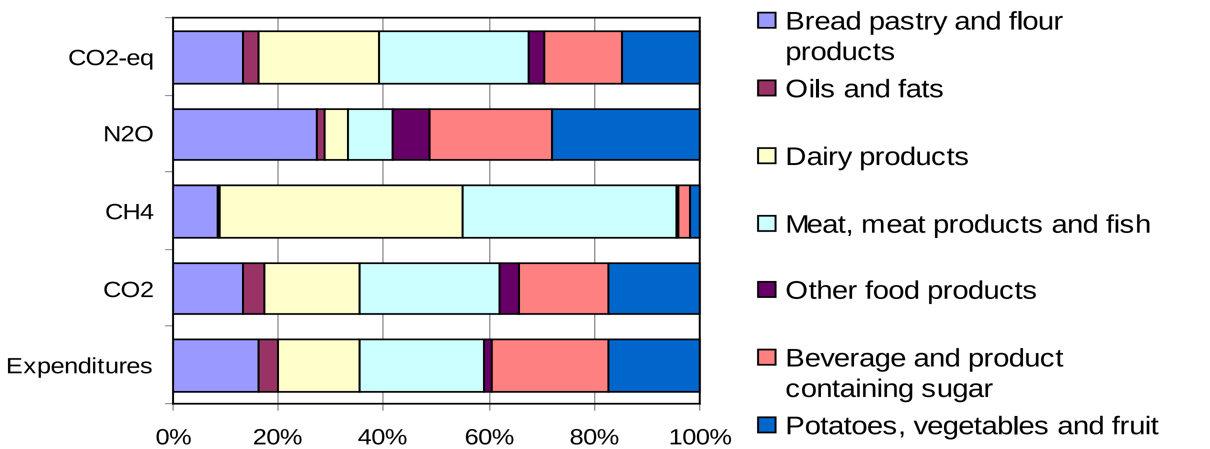
The initial data requirement for using Hybrid Analysis in a country is relatively high. A prerequisite is a detailed Input-Output Analysis including data about energy use and further environmental issues and information about direct impacts for the production of a range of basic products (e.g. fertiliser, pesticides). So far we do not know of a Hybrid Analysis dealing with a range of environmental aspects. However, once a database and methodology has been established for a country it is relatively easy to investigate additional products.

Case studies on consumption

Extensive case studies on consumption based on a Hybrid Analysis have been published mainly in the Netherlands. They show for example that lower environmental impacts for cooking of pre-prepared products can in some cases compensate for the higher impacts during the production stage (Brouwer 1998; Kramer & Moll 1995; Kramer et al. 1998; Kramer 1998; Kramer et al. 1999).

Fig 2.4 shows the results of a Hybrid Analysis for different greenhouse gases given by Kramer et al.(1999) for the Dutch consumption patterns in 1990. Meat accounts for 23.5% of the expenditures, but for 8.2% and 40.4% of the N_2O and CH_4 emissions due to food consumption in the Netherlands, respectively. Milk and vegetables are other important product groups with regard to greenhouse gas emissions.

Fig. 2.4 Distribution of Dutch annual spending over seven food product categories and contribution of these categories to the greenhouse gas emissions related to Dutch food consumption (Kramer et al. 1999).



Summary of strengths and weaknesses and utility for policy-making

Hybrid Analysis is a good method to investigate efficiently the energy use or a limited list of emissions of a wide range of consumer products. The possibility to combine these data with household expenditure statistics is an exclusive advantage of this method. Hybrid Analysis is useful to evaluate the share of different products (e.g. meat, vegetables, etc.) with regard to the energy use or for some environmental impacts of consumption patterns or diet choices. The method can also be used to analyse the development over time and to forecast impacts due to changes of consumer behaviour. In this sense it can be more specific than using IOA data, but it will be less detailed than a full LCA.

The main drawback is the high initial effort for the first establishment of an IO-database of a country. The analysis is not very specific with regard to the environmental impacts considered. It would seem that, with the availability of large LCA databases, interest in Hybrid Analysis has waned. The method does not simplify the work of data collection for single case studies and thus has attracted less attention in the recent past. But the method might regain interest if thousands of products e.g. in a supermarket were to be investigated.

2.4.4 **Material Flux Analysis (MFA)**

Introduction

Material Flux Analysis (MFA) quantifies the flows of “indicator elements” (e.g. phosphorus, carbon, water) or the energy use within a geographical or functional system. MFA has been developed to understand the metabolism of the anthroposphere. All in- and outputs of system are accounted for. MFA for household consumption distinguishes between different activities such as nutrition, housing, mobility, etc..

Parts of life cycle, emissions investigated, indicators and aggregation principles

Some studies consider all parts of the life cycle of the products that are in- and outputs to and from the system investigated, while others account only for the direct in- and outputs of substances. Only those products with an important flow of the materials investigated are considered. Indicator elements used by MFA are for example carbon, sulphur, water or metals. All chemical compounds of these elements are summed up. Some studies investigate energy flows similar to the CERA. The indicator elements represent resources or chemical elements that are considered important for certain environmental impacts. There is no weighting scheme to assess the overall environmental importance of the different chemical compounds of an element (e.g. CO_2, CH_4 and phenol emissions to water are summarised by their carbon content) or to summarise all elements to one indicator.

Data requirements and availability

Data stem from the investigation of production facilities, material accounts of a company as well as national or regional statistics of e.g. food or energy consumption. Background databases have been published (e.g. EUROSTAT 2001).

Case studies on consumption

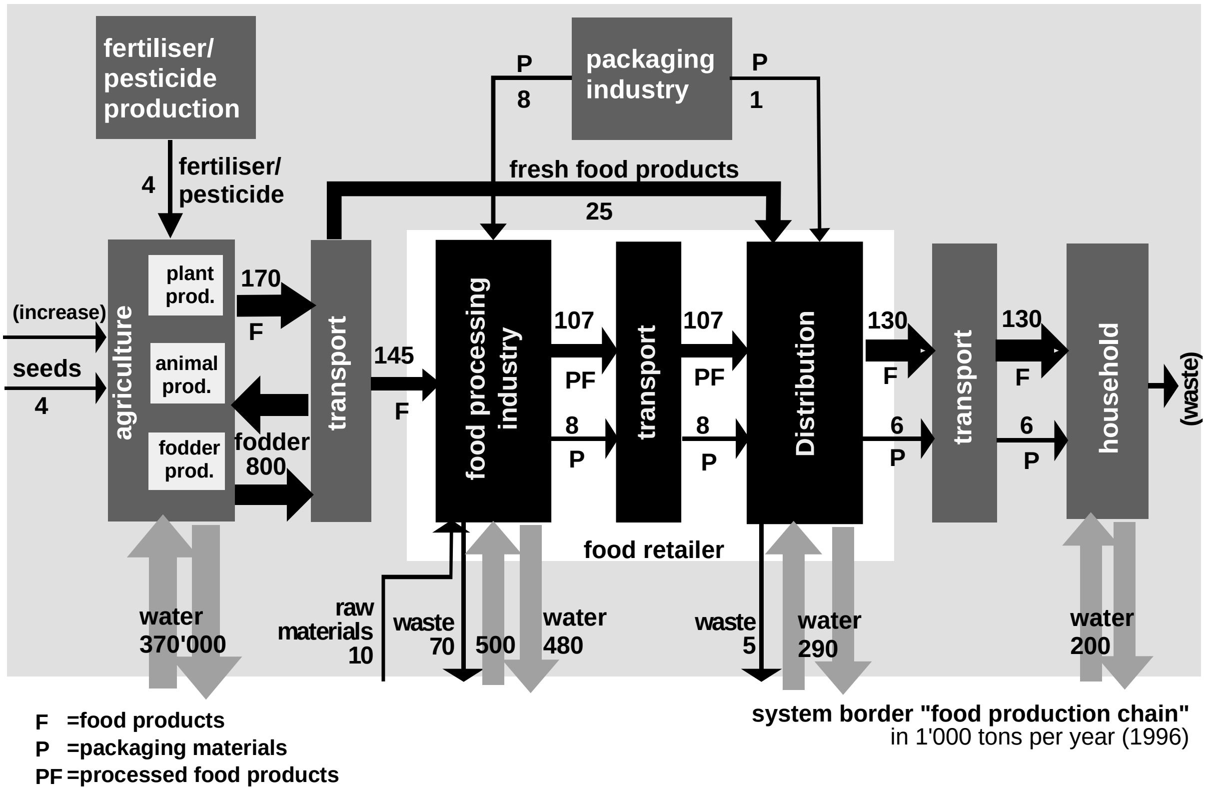
BACCINI *et al.* (1993) analysed the material fluxes through the households of a city. Nutrition was one of the specific activities investigated and includes all preceding stages of food production, but not e.g. cooking (falls under housing) or toilet effluents (cleaning). Food consumption is mainly responsible for phosphorus fluxes in a city. Chlorine and sulphur flows are also dominated by the nutrition activity.

Most MFAs focus on whole countries. Case studies cover Switzerland (Rubli et al. 2005) and several EU countries (van der Voet et al. 2005).

FAIST *et al.* (1999a; 1999b) investigated the material flows due to the activities of a food retail centre in Switzerland. Fig 2.5 shows an example from this research work. The largest turnover of materials occurs in agriculture. It is mainly caused by meat and dairy production. 800’000 tons of fodder are needed to produce

170’000 tons of milk, animals and other food products. The analysis shows an equal distribution of energy requirements in agriculture, households and for the in-between processes (transports, processing, retailing). A change in consumption patterns could influence the energy efficiency (ratio of energy use to consumption of nutritional energy). The retailer should consider the whole food chain and not solely energy uses within own facilities. The MFA shows the dominance of phosphorus, nitrogen, water and land due to the food consumption of households (Faist et al. 1999b).

Fig. 2.5 Current material fluxes in the food production chain of a Swiss retailer. The size of most arrows is proportional to the magnitude of the mass flows that they represent. Exceptions are made for the flows of water and fodder, because these flows are too large. The flow of waste from households is not assessed (Faist et al. 1999b).



Summary of strengths and weaknesses and utility for policy-making

The MFA is valuable for understanding the mechanisms of certain substance flows in a system. It helps to identify the main sources or contributing processes for the emissions of elements that are known to contribute to an environmental problem in the system investigated. Scenarios of technical changes can be modelled by MFA. The method helps policy-makers to identify key points or options in a system where the flows of substances can be influenced. It is flexible, because important elements are defined on a case-by-case basis. An extension to economic aspects allows a modelling of impacts due to political measures such as energy taxes.

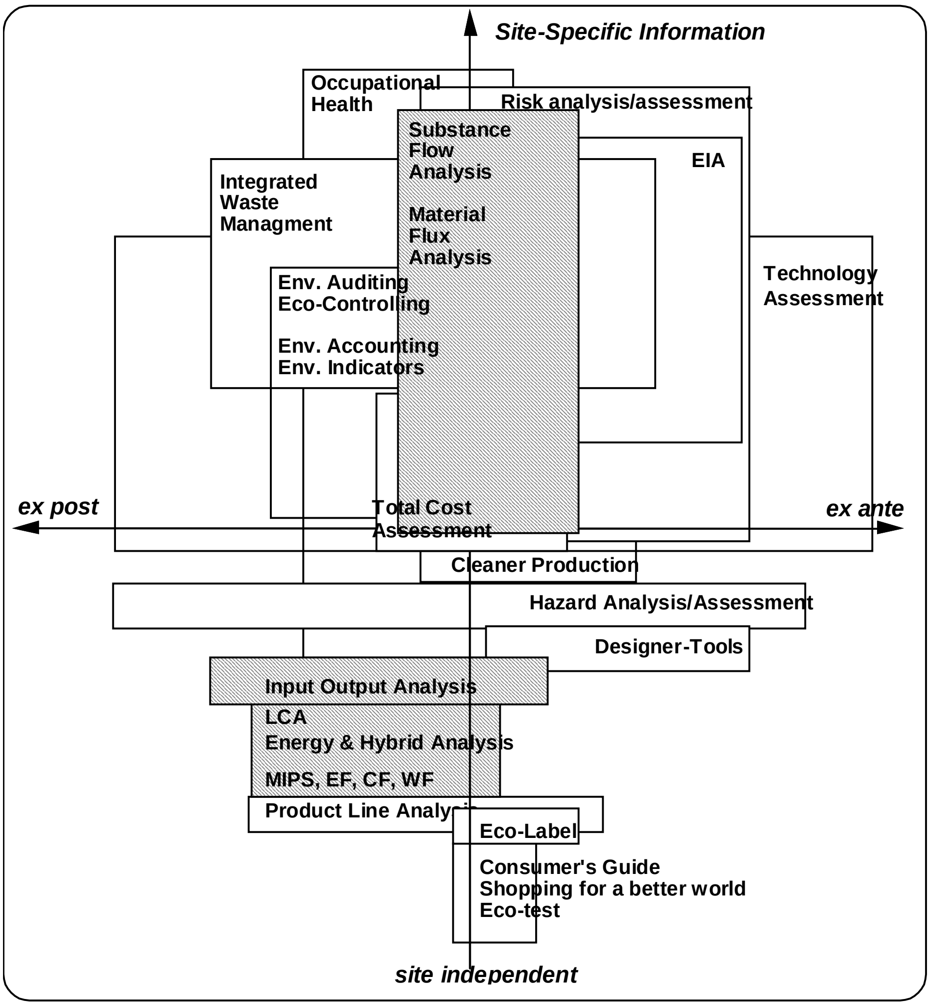
Until now no method to highlight and compare the environmental relevance of different chemical compounds investigated in an MFA was used. A recent study just summed up the characterised results for certain environmental indicators (see section 3.2.2). Normally, the results are only applicable for the individual investigation and problem.

2.5 Positioning of different methodologies within time and space

Different tools for environmental management can be positioned with respect to their treatment of the very important dimensions of space and time. Fig 2.6 shows an overview of different environmental management tools in the time-space area (Hofstetter 1998).

The methods can cover different types of decisions. Thus, for example, Material Flux Analysis is a method to generate site-specific information for current and past situations. LCA and cumulative energy requirements analysis focus on product specific information. From Fig 2.6 it is obvious that no method fits every analysis goal. One needs to choose the appropriate tool to answer the question up for decision. The main differences between the methods concern site or product specificity, the environmental indicators and the databases used.

Fig. 2.6 The location of environmental management methods in the time-space area. "Time" addresses the descriptive or predictive power of the tools and "space" addresses the spatial differentiation within the tool. Methodologies discussed in this context are shaded with sloping lines. All tools in the lower half of the figure are site-independent (ordinal scale), EIA = Environmental Impact Assessment (modified from Hofstetter 1998:25).



2.6 Levels of decision-making addressed

Table 2.4 shows the levels of decision-making (DML) at which the different actors have possibilities for environmentally relevant actions. JUNGBLUTH *et al.* (2000) assume that consumers have the widest range of possibilities open to them to behave in an environmentally sound manner.

A consumer can decide to shift money from one field of need (e.g. mobility, nutrition) to another. This might be environmentally relevant if one spends, for example, less on travelling, but more on eating in an organic-food restaurant. Within the need field of nutrition one can decide, for example, to eat mainly in fast-food restaurants or to consume only vegetarian food. Closely related is the level of decision among different product groups (vegetables, meat). In one product group (e.g. meat, vegetables), one can choose to buy more pork or more beef. Purchasing decisions within one product category (e.g. cabbage, salad, etc.) with different products (e.g. cauliflower, red cabbage, etc.) are also possible e.g. depending on the availability of certain products. Often the choices among variants of a product (e.g. organic or conventionally grown carrots) are addressed by consumers. If the decision has been made for one product, there is still a possibly relevant choice, e.g. for a certain packaging. The consumer can also decide about the processing (e.g. refrigeration, cooking) of a product in the household. All levels of decision-making are relevant for the overall environmental impacts of individual consumption patterns.

Other actors in the food chain do not have such a variety of environmentally relevant decisions. They are more dependent on the market and on decisions of cooperating actors. Decisions about processing, pre-products or additives are mainly relevant for the producing or processing actors (food industry). An ice-cream producer can decide for example about the use of certain raw materials, or reduce the amount of energy used in the factory, but he or she is unlikely to consider producing beer instead of ice cream on environmental grounds.

The higher levels of decision-making are quite often more relevant for behavioural changes and reduction of total environmental impacts than the lower DML. Thus the focus of interaction with the consumers should be to guide decisions at these higher levels of decision-making.

Tab. 2.4 Levels of environmental decision-making for different actors in the food chain and appropriate methods for an analysis of these decisions (Jungbluth et al. 2000).

Farmer	Food-industry	Trader	Consumer	Waste management	Level of decision making (DML)	Example	Evaluation method
					9 All need fields	Mobility, nutrition,...	IOA, EF, HA, MIPS, MFA, CF
					8 One need field	Home cooking, restaurant,…	MFA, MIPS, IOA, HA, EF, CF
					7 Product groups	Vegetables, meat,...	HA, MFA, EF, LCA, CF
					6 One product group	Beef, pork, poultry,…	CERA, LCA, HA, MFA,CF
					5 Product category	Cabbage, salad,...	LCA, CERA, HA, MFA, CF
					4 Variants of a product	Organic, conventional	LCA, CERA, MFA, CF
					3 One product	Types of packag-ing,...	LCA, WASD, CERA, MFA, CF
					2 Processing	Cooking, refrigeration,…	LCA, CERA, MFA, CF
					1 Pre-product and additives	Cleaning agents,…	LCA, CERA, MFA, CF

The actor's influence on environmental impacts:

	Directly: The actor can reduce environmental impacts directly.
	Indirectly: The actor can reduce environmental impacts in co-operation with other actors in the life cycle.

Different levels of decision-making introduced in Table 2.4 can be addressed with different methods. The levels (1.–4.) of decision-making are often investigated with a life cycle assessment (e.g. decisions about which pre-products are to be used in processing). Decisions about different need fields entail more serious changes than decisions about different variants of a product. Today, energy, EF or Input-Output Analysis is used in order to support environmental decision-making in the higher levels of the above model, but LCA is also suitable.

System boundaries, level of detail and workload depend on the DML addressed. This is also further explained with examples in case studies provided in chapter 5. For the lower level, a substantially higher level of detail is necessary than on the higher DML. Thus, the workload would also be considerably higher if one wants to exactly investigate the differences between e.g. different types of salad than if one wants to establish one average value that can be compared with the value of meat.

For comparisons on one given DML it is necessary to define a clear functional unit (e.g. comparing different types of washing powder by the dosage used for one wash) while for others it is sufficient to use the actual physical amount (e.g. 100 grams of yoghurt). At the end every EPI can only be used to make predefined comparisons, but an EPI does not allow an absolute statement on a product saying e.g. that this product does not harm the environment. The EPI can only be used to compare one product with another.

With regard to environmental product information, it should be clearly defined which level of decision-making is to be mainly supported with the information. Due to the necessary setting of system boundaries it is not possible to find one methodology and approach that can be used to address all levels of decision-making at the same time. The two lower levels of decision-making (DML 1-2) cannot be directly addressed by environmental information on the product. Here, only recommendations can be given to the consumer.

Even if one method is suited to be used on different levels of decision-making, this does not mean that is possible to provide meaningful environmental information on the product that can be used for cross comparisons over different levels. In every approach it has to be decided which type of decisions on which level of decision-making is to be addressed with the information.

2.7 Comparison of basic methodologies based on selected criteria

In order to choose the appropriate method for a given problem or question it is necessary to know the main attributes of each method. The following tables show a summarising overview of different methods described in the previous chapters and the level of decision-making that can be addressed with the different methods (see Table 2.4). Table 2.5 focuses on methods which are mainly defined by the environmental indicator that is considered for the evaluation. Table 2.6 focuses on methods which are defined more by the way the process chain analysis is conducted and which can be used with different types of indicators.

According to the criteria used in this feasibility study, the methods in Table 2.5 do not fulfil the criterion of being meaningful concerning the range of environmental impacts covered as they only focus on single issues. Input-Output Analysis and Hybrid Analysis are difficult to apply in Switzerland due to the lack of the necessary background data. Material flux accounting is usually not appropriate to investigate and compare individual products and services. Thus, LCA is the most appropriate method to be used in environmental product information for consumer products.

Tab. 2.5 Summary of the criteria for evaluating different indicator driven methods for investigating the environmental impacts of consumer products. Level of decision-making addressed by the methods (product = product and/or service).

Method	Principle	Indicators and weighting principle	Data availability	Methodological background	Strength, Purpose, Level of decision-making	Weaknesses
Cumulative Energy Requirements Analysis (CERA), Process-Chain Analysis	Energy use summed up for all stages in the life cycle of a product.	Aggregation (with different methods) of the primary energy content of energy resources used for the production of a product (e.g. MJ/kg).	Generally good.	Long tradition with publications in various journals, such as Energy Policy, and published guidelines.	Easy to apply; single indicator and several databases available. Analytical tool that can be used for information of consumers (DML 1-6)	Energy is not necessarily a good indicator for all types of environmental impacts caused in the life cycle (e.g. agriculture).
Carbon Footprint	Emission of greenhouse gases summed up and characterised for all stages in the life cycle of a product.	Characterisation of contribution to global warming potential (CO_2-eq). Time horizon usually 100 years according to IPCC guidelines.	Generally good. Some specific modelling problems e.g. land-use change and N_2O from agriculture.	Became quite popular in the recent 2-3 years with the climate change being a top priority on the agenda. Several diverging standards hinder comparability.	Easy to apply; single indicator and several databases available. Analytical tool that can be used for information of consumers (DML 1-6)	GWP is not necessarily a good indicator for all types of environmental impacts caused in the life cycle (e.g. agriculture). Different standards need better harmonisation.
Ecological Footprint (EF)	Investigation of actual and theoretical land uses over the full life cycle of certain activities.	Calculation of the theoretical area necessary to deliver goods and services with data about direct land use and indirect assessment of the area for absorbing CO_2 emission from fossil fuel use.	Case studies mainly not specific for food consumption. Harmonised data on the level of nations.	Basic idea elaborated in a Ph.D. thesis. Email discussion list. Articles in Ecological Economics.	Easy to communicate as a proxy indicator for sustainability. (DML 7-9)	Fixed weighting scheme that disregards the emissions of toxic substances that are assumed unsustainable.
Water Footprint	All water consumption is summed up over the life cycle. Regionalisation necessary for better analysis.	Quantity of water used for a product. Differentiation of different types of water quality or uses.	Some specific databases. Main problem is regional accounting.	Became more popular in recent years, but first studies date back to the 1990s.	Water scarcity is seen as one of limitations for the further growth of human population. Not necessarily a good tool for decision-making but for awareness-raising.	Regionalisation of inventory is necessary in order to characterise different types of water uses in a life cycle. Thus, LCA databases are difficult to apply.
Material Intensity per Service Unit (MIPS) or Ecological Rucksack (ER)	Investigation of materials moved over all stages in the life cycle of a product.	Aggregated mass flows. All masses are added non-weighted in 5 categories (e.g. kg/kg product).	Case studies mainly from Germany. No good public databases.	Mainly developed by the Wuppertal-Institute in Germany.	Useful as a proxy indicator to communicate the need to change consumption patterns, and as a tool to monitor progress in dematerialisation. Single indicator for mass and energy (DML 8-9)	Fixed weighting scheme that does not reflect the environmental impacts caused by the masses moved. Considers only inputs, but no outputs to the environment.

Method	Principle	Indicators and weighting principle	Data availability	Methodological back-ground	Strength, Purpose, Level of decision-making	Weaknesses
WASP/WASD and other investigations of trans-ports.	Assessment of trans-ported distances over some or all stages of the life cycle of a product.	All modes of transport are aggregated. Indicator is the total distance of freight movement in kilo-metres or indication of tonne-kilometres.	No good public databas-es for different transport steps. Information rela-tively easy to obtain from producers.	Neither standardised method nor community. Mainly developed by single persons in Germa-ny and Sweden. Single case studies for food products.	Easy to communicate. Yardstick for the analysis of transport related im-pacts due to globalisa-tion. (DML 3).	Transports do not show a full picture for the envi-ronmental impacts caused. Different modes of transportation need to be distinguished.

Tab. 2.6 Summary of the criteria for evaluating different inventory driven methods for investigating the environmental impacts of consumer products. Level of decision-making addressed by the methods (product = product and/or service).

Method	Principle	Indicators and weighting principle	Data availability	Methodological back-ground	Strength, Purpose, Level of decision-making	Weaknesses
Life Cycle Assessment (LCA)	Investigation of environ-mental impacts over all stages in the life cycle of a product.	Different characterisation methods by which to assign elementary flows to impact or damage categories based on their effect or damage poten-tial (e.g. global warming potential per kg) or based on political targets.	Good background data for different types of products and services. Several case studies on all types of consumer products. Specific soft-ware tools.	Different journals, LCA group within SETAC, ISO-standard, specia-lised software for data analysis.	Structured and flexible approach for inventory and weighting principles. Detailed analysis of envi-ronmental impacts (DML 1-7)	High data requirement for individual products. Some methodological problems while accounting for spe-cific environmental prob-lems, e.g. noise, desali-nation, erosion.
Input-Output Analysis (IOA)	Economic flows among different sectors of econ-omy are used to calculate energy (or environmen-tal) intensities for goods from different economic sectors.	Primary energy content of energy resources used (pollutants emitted) in a sector per economic value created (energy or environmental intensity, e.g. MJ/CHF).	Good in some countries (e.g. USA, Germany, the Netherlands), poor in others (e.g. Switzerland).	Developed as a tool for economic research. Publications in different journals.	Easy to apply in the anal-ysis of a full range of household activities. (DML 8-9)	Not specific for different environmental impacts and not suited for deci-sions about individual products because of high level of aggregation.
Hybrid Analysis	Combination of input-output and process-chain analysis to calculate the energy intensity of a large number of con-sumed products.	Primary energy content of energy resources used per household expendi-ture for a certain product (energy intensity, e.g. MJ/CHF).	High initial effort in a country. Good database for the Netherlands.	Developed mainly in the Netherlands.	Easy to apply for the analysis of a range of products. (DML 4-9).	High initial effort in a country to establish an input-output database and the basic methodolo-gy. No standardised software available.

Method	Principle	Indicators and weighting principle	Data availability	Methodological background	Strength, Purpose, Level of decision-making	Weaknesses
Material Flux Analysis (MFA)	Assessment of material flows or energy uses due to certain activities in a system defined in most cases defined by geographical boundaries (e.g. household, factory, country, EU).	Analysis of indicator elements or energy use regarded as environmentally relevant, and aggregation of chemical substances with the content of the indicator element (e.g. total C mass from CO_2, CH_4, etc.).	Data from different statistics and information about production processes. Data availability depends on the case study investigated.	Several working groups in e.g. Germany, Austria, Switzerland.	Good for a system analysis and flexible in terms of weighting environmental problems. (Different levels between 1 and 9 are addressed in case studies).	Equivalence of different emissions with unequal environmental impacts. No clear procedure to choose indicator elements and to assess their environmental relevance.

3 Overview of national and international activities

There are several ongoing initiatives for labelling products or for providing information about environmental impacts. Many of these initiatives aim to calculate “carbon footprints”. In order to learn more about possible methods and approaches some of the most important initiatives on a national and international level are analysed in this chapter. Due to the multitude of approaches, this can not be a complete description. The field is also developing rapidly and we only considered information available until October 2009.

3.1 Criteria for the investigation

The following criteria are applied to structure the comparison and analysis of the existing initiatives. They were developed by us based on the preliminary research questions and then discussed with the steering group:

- Range of product groups covered
  Is the approach designed for a specific product group or can it be used for all types of consumer products? How many products have already been labelled or investigated?
- Parts of the life cycle covered or neglected
  Does the approach include the full life cycle? How does it deal with the consumption and end-of-life phase?
- Guidelines and methodology for inventory modelling
  Are there guidelines for the methodology? Who has published and reviewed them? Is the procedure described? Does the EPI follow the ISO 14020 standard for environmental labels and declarations (International Organization for Standardization (ISO) 2000)?
- Impact assessment method used
  Which LCIA method is used in the analysis of environmental impacts?
- Communication approach
  How are the results communicated to the end-user? Is the information quantitative, absolute or relative? Is more detailed background information available?
- Organisational aspects of investigating the information (producer, public, NGO)
  Which actors are involved in elaborating the information? Who provides EPI? Who pays for the process?
- External review and quality assurance
  Is there an external review? Is this independent from interests of the producer or label organisation?
- Auditing of the investigated supply chain
  Is there transparency about the data and assumptions used? Is the full process transparent and reproducible? What is done in case of conflicts between producers or with diverging interests?

3.2 Case studies on priority setting

In this first section, we describe some case studies. They deal with priority setting in product policy and with an assessment of the environmental impacts caused by consumption patterns. These study do not describe a labelling scheme nor lead directly to such.

3.2.1 EU project on Integrated Product Policy

The European Commission announced to identify and stimulate action on products with the greatest potential for environmental improvement within its Communication on Integrated Product Policy. This work is carried out sequentially in **three phases** that are described in the following sections.

Source: *http://ec.europa.eu/environment/ipp/identifying.htm*

EIPRO – Environmental Impact of PROducts

The European Commission realised the EIPRO project in order to identify the products that are consumed in the EU having the greatest environmental impact from a life cycle perspective. Consumption of society was grouped into almost three hundred product categories and assessed in relation to different environmental impacts, such as acidification, toxicity, global warming, ozone depletion, etc.

A first study (Tukker et al. 2006) showed that products from only three areas of consumption - food and drink, private transportation, and housing - together are responsible for 70-80 percent of environmental impacts of private consumption. These products also account for some 60 percent of consumption expenditure altogether. These findings are based on a review of existing studies plus supplementary work on an Input-Output methodology developed by the JRC-IPTS in cooperation with organisations of the ESTO research network.

IMPRO - environmental IMprovement of PROducts

The second phase of the work on IPP by the EU attempted to identify possible ways in which the life cycle environmental impacts can be reduced for some of the products that are among those with the greatest environmental impacts. The analysis first considered improvement potentials which are technically feasible. Following this, the associated socio-economic impacts were considered and analysed. The analysis covered the following aspects:

- Estimate and compare the environmental impacts of the products under a full life cycle perspective.
- Identify the main environmental improvement options related to the products addressing all the different life cycle stages and estimate the size of the environmental improvement potentials.
- Assess the main improvement options regarding their feasibility and potential social and economic impacts.
- What could be achieved at the various life cycle stages and what would be overall the environmental benefit of these various options?
- What are the potential trade-offs between the different options and between the different types of environmental benefits?
- What are the different barriers (economical, social, market, etc.)?

The first three groups of products that are among those with the greatest environmental impacts are currently analysed:

- passenger cars (finished)
- meat products (ongoing)
- housing (ongoing)

Policy implications

Following the first and second study, the European Commission will in the **third phase** seek to address policy measures for the products that are identified to have the greatest potential for environmental improvement at least socio-economic cost.

3.2.2 Policy Review on Decoupling

Short summary of the study “Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries” (extract from van der Voet et al. 2005):

“This study has been conducted within the framework of the EU Thematic Strategy on the Sustainable Use of Natural Resources (Resource Strategy), which is currently in development. The objective of the Resource Strategy is described as: "ensuring that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment and breaking the linkages between economic growth and resource use". The question that is the subject of this study is how to measure decoupling and how to monitor progress on the decoupling road. For monitoring, indicators or measurements are required that encompass the abovementioned characteristics: these indicators should be applicable at the (supra)national level, they should indicate a total level of environmental impacts, related to the use of materials or resources, and should enable creating time series in order to monitor progress.

In earlier studies, the Domestic Material Consumption over GDP (DMC/€) has been put forward as such an indicator. DMC measures the material resources, which are directly consumed within a national economy and are put forward as indicators, however indirect, for environmental pressure. The reasoning behind this is that in the end each kilogram of material entering an economy has to come out at some moment as waste or emissions.

While this is undoubtedly true, it is at the same time true that there are large differences in environmental impacts between different resources or materials. A kilogram of sand does not have equal impacts as a kilogram of copper, or meat, or coal. The potential environmental impacts of the different materials or resources should be considered as well as the weight or volume of their use. In the end, it is the environmental pressures and impacts, respectively, which should be decoupled from economic growth, not their use per se. In this study, it was attempted to develop an indicator combining information on material flows with information on environmental impacts. This indicator is called EMC, Environmentally weighted Material Consumption. In addition, a first attempt was made to define an indicator for land use at the same basis, i.e. to be used as a measure for decoupling. These indicators are applied for the 25 EU countries and 3 Candidate countries. Time series are made for the former EU-15 countries from 1990 - 2000, and for the newly accessed and candidate countries from 1992 - 2000. The results are compared with the DMC for the same countries and time period. This sheds some light on the discussion with respect to the extent to which the DMC indeed can be regarded as a proxy for environmental pressure.

Next to indicator development, this study focuses on explaining these indicators. Both for the DMC and the EMC explanatory variables were defined and tested. Policies affecting material flows have been identified and an assessment has been made of their influence. Moreover, correlations were made between DMC and EMC. In this way, we hope to shed some light on the reasons for differences between countries for both variables, as well as on the debate over the usefulness of DMC as an indicator for environmental pressure.”

The EMC indicator is an unweighted aggregation of 10 impact categories. The following impact categories are included in EMC (according to Best et al. 2008). It is not mentioned which LCIA method has been used for characterisation (presumably a version of the CML methodology, but in some tables also categories of Eco-indicator 99 (H,A) are mentioned).

- Climate change
- Human health
- (Land use)[14]
- Stratospheric ozone depletion
- Eco-toxicity (aquatic, terrestrial, marine), three indicators weighted as one category
- Human toxicity
- Photo-oxidant formation
- Acidification
- Eutrophication
- Ionising radiation
- (Final solid waste generation)[15]

[14] We could not find information on whether this is a characterised indicator or just an addition of square metres.
[15] We could not find information on whether this is a characterised indicator or just an addition of kilograms.

The authors calculated with the ESU-ETH database of 1996 a total EMC. For that purpose, data on important products have been linked with the LCIA results for the above-mentioned impact categories of these products from the old ETH-database. The LCIA results are normalised and added up to give "Environmentally weighted Material Consumption". In order to prevent double counting, some materials consumed were excluded from the analysis.

The authors try to derive conclusions out of the calculation and the comparison with indicators on GDP or DMC. They found, for example, that at the most detailed level, the level of individual materials, there seems to be no relation whatsoever between a material's consumption and its impacts. The authors also found out the EMC is growing faster than DMC. This statement is based on data collected in one year only.

Source: *http://www.leidenuniv.nl/cml/ssp/projects/dematerialisation/index.html*

3.2.3 Potential of the Ecological Footprint for monitoring environmental impacts

A recent EU study investigated the potential of the Ecological Footprint for monitoring environmental impacts from natural resource use (Best et al. 2008). It builds partly on the methodology described in section 3.2.3 (van der Voet et al. 2005). The Ecological Footprint is seen as a useful indicator for assessing progress on the EU's Resource Strategy and is considered to be unique among the 13 indicators reviewed in this study in its ability to relate resource use to the concept of carrying capacity. The indicator is most effective, meaningful and robust at aggregate levels (national and above). Further improvements in data quality, methodologies and assumptions are required. This study identifies a short- and medium-term research agenda for the Ecological Footprint that focuses on experts' top recommendations for further development of the methodology. To effectively monitor EU progress on the Resource Strategy, additional indicators are considered to be required.

This study recommends the adoption of a small indicator basket consisting of four resource indicators: Ecological Footprint (EF), Environmentally-weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP) and Land and Ecosystem Accounts (LEAC). The identified basket of indicators shall be applied to monitor de-coupling of economic growth from environmental impacts as well as illustrating the effectiveness of a number of specific policies aiming at a more sustainable use of natural resources (especially energy and climate policies, agriculture and forestry policies, material policies and spatial planning/urban planning). Capturing the geographical distribution of pollution impacts and impacts on ecosystems and biodiversity requires the use of indicators additional to those in the basket. Only EF and EMC are seen by the authors as appropriate for product investigation while the other indicators are more suitable on a regional or national level.

3.3 Environmental labels, standards and product information

3.3.1 ISO standard 14020ff for labels and product declarations

The most important standard for environmental labels and declarations is the ISO 14020 (International Organization for Standardization (ISO) 2000). This document provides guidance on the goals and principles that should frame all environmental labelling programmes and efforts, including practitioner programmes and self-declaration. There are three types of environmental labels defined by ISO.

Type I, described in ISO 14024, are environmental labels with criteria set by third parties (not the manufacturer). They are in theory based on life cycle impacts and are typically based on pass/fail criteria. ISO 14024 provides the principles and protocols that third-party labelling, "seal" or "practitioner" programmes should follow when developing environmental criteria for a particular product. The intention is to standardise the criteria used by a multitude of such programmes worldwide and to generate greater agreement among stakeholders.

Type II, described in ISO 14021, are environmental labels based on the manufacturers' or retailers' own declarations.

Type III, described in ISO 14025, are declarations that provide quantitative details of the impact of the product based on its life cycle. Sometimes known as EPDs (Environmental Product Declarations), these labels are based on an independent environmental assessment of the life cycle of the product. The data supplied by the manufacturing companies are also independently reviewed.

In ISO 14020, 9 principles are declared that should be followed by Type I, II, and III labels:

1. *Environmental labels and declarations shall be accurate, relevant and not misleading.*
2. *Procedures and requirements for environmental labels and declarations shall not be prepared, adopted, or applied with a view to, or with the effect of, creating unnecessary obstacles to international trade.*
3. *Environmental labels and declarations shall be based on scientific methodology that is sufficiently thorough and comprehensive to support the claim and that produces results that are accurate and reproducible.*
4. *Information concerning the procedure, methodology, and criteria used to support environmental labels and declarations shall be available and provided to all interested parties.*
5. *The development of environmental labels and declarations shall take into consideration all relevant aspects of the life cycle of the product.*
6. *Environmental labels and declaration shall not inhibit innovation, which maintains or has potential to improve environmental performance.*
7. *Any administrative requirements or information demands related to environmental labels and declarations shall be limited to those necessary to establish conformance with applicable criteria and standards of the labels and declarations.*
8. *The process of developing environmental labels and declarations should include an open, participatory consultation with interested parties. Reasonable efforts should be made to achieve a consensus throughout the process.*
9. *Information on the environmental aspects of products and services relevant to an environmental label or declaration shall be available to purchaser and potential purchaser from the party making the environmental label or declaration.*

Furthermore, ISO states that environmental labels and declarations including those developed or operated in a government-sponsored way shall be voluntary in nature and they shall demonstrate transparency through all stages of their development and operation. Labelling programmes shall be able to demonstrate that sources of funding do not create a conflict of interest. Labels should follow one ISO Type and Type I and Type II labels should not be merged during communication together with a Type III environmental declaration.

The ISO standard can clarify the basic principles of good environmental declarations. It can be an important normative basis for any approach developed for environmental product information.

3.3.2 Environmental Product Declaration (EPD)

Environmental Product Declaration (EPD) is a voluntary tool to communicate the environmental performance of a company’s product. The overall goal of an EPD is to provide relevant, third party verified, and comparable information to meet various customer and market needs. The international EPD®system is one possible approach. It has the ambition to help and support organisations to communicate the environmental performance of their products (goods and services) in a credible, transparent, and understandable way.

The system has developed general methodological instructions (EPD 2008). The methodology for a particular product group is than defined in product category rules (PCR, e.g. PCR CPC 17 2007 for electricity, stem, etc.). Different producers or associations openly discuss the PCR for a specific product group. So far about 130 such PCRs have been developed or initiated in this system. They cover groups such as mineral water, milk, sparkling wine, windows, fertiliser, etc.

For the specific product, environmental impacts for a list of impact categories are evaluated in an LCA from cradle to gate. There is no one-score weighting system, but a declaration of certain pollutants and resource uses (e.g. water consumption, energy carriers, wastes) as well as results for LCIA impact categories such as climate change, resource use, acidification, eutrophication, etc. as defined in the PCR. An own list of characterisation factors has been published (annexe B to EPD 2008) and is available in LCA software such as SimaPro.

The underlying data used in the LCA need to be externally verified. EPDs are mainly set up for business-to-business communication. However, communication to end consumer is also possible. The producer is responsible for the LCA calculations, which are documented in a report and approved by a technical committee linked to the International EPD Consortium. The EPD documents for single products and producers are publicly available on the homepage of the EPD®system (e.g. Electrolux 1997).

The EPD®system is a non-profit organisation that was founded based on a cooperation between interested parties from any country wanting to join the activities. So far partners seem to stem mainly companies and research institutes from Sweden and Italy and include the European Commission’s Joint Research Centre.

Sources: EPD®system: *www.environdec.com*. Other approaches for EPDs are carried out in Norway (*www.epd-norge.no*), Japan (*www.jemai.or.jp*), USA (*www.scscertified.com*), and South Korea (*www.scscertified.com*).

3.3.3 Projet d'affichage environnemental dans le cadre de la loi Grenelle (FR)

AFNOR (Association Française de Normalisation) developed guidelines for environmental product declaration. An annex describing the methodology of production declaration for different groups of products has been published. This section describes the principles elaborated by AFNOR and does not refer to an existing label (AFNOR 2008).

The guideline proposes the establishment of a typology for the major consumer goods, which includes material and immaterial goods (e.g. services). This typology defines categories of products which are similar in production and other life cycle relevant aspects. As it is acknowledged that the direct comparison between different kinds of products is difficult to obtain, it is postulated that comparability should be provided only within categories of products. The methodology of the LCA shall be defined for each category of products.

A first evaluation for each product category must be carried out using standardised methods for life cycle assessment (ISO 14040 and 14044). The assessment has to include the product’s entire life cycle. Based on these preliminary assessments the evaluation standards for the individual product categories are developed. These standards define the system boundaries, allocation rules, cut-off criteria and environmental indicators.

Further assessments are carried out following the standardisation rules. Hence, it is yet to be defined which parts of the life cycle have to be included in the assessment procedure. For each product group the mandatory parts will be defined, according to the importance of the individual stages of the life cycle. If it has proven relevant, the supply chain might be an integral part of the life cycle assessment of a product category and in these cases must be auditable.

The environmental indicators used in the declaration can vary from one product group to the other, but they must be investigated according to the ISO standards 14040 or 14044. All product categories must take into account the greenhouse gas emissions and the impact on biodiversity. The six Kyoto greenhouse gases must at least be included in the assessment. Further GHG emissions from soil due to land-use changes have to be considered.

The declaration should be compulsory for all consumer goods. The producer is responsible for the declaration and pays for the costs arising from the declaration process. If the data collection is economically unreasonable, the producer can revert to a public database, which provides standard values. The public database is supervised by ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie).[16] The review procedures for the producer's declaration are not described in detail.

3.3.4 Plant specific labelling of energy systems (naturemade star)

In Switzerland the privately initiated ecolabel "naturemade star" ensures the environmental and ecological quality of electricity from renewable energy sources in an approach that incorporates life cycle thinking. The evaluation method involves a simplified and partly site-specific life cycle assessment using the Eco-indicator 99 (H, A) impact assessment method. In a first step, detailed LCA case studies are made for energy conversion plants and technologies, which are candidates to receive the "naturemade star" label. Technology-specific parameters are identified that dominate the outcome of the LCA and for which data are available to the owner or operator of the energy conversion plant at issue. For photovoltaics for instance, key parameters are the annual production, the type of solar cell (single- or multicrystalline), and the kind of installation (building integrated or mounted). Based on the knowledge gained with the detailed LCA, parameter models for electricity from photovoltaics, wind and hydroelectric power, biogas of various sources and wood have been established on a spreadsheet basis. They are easy to handle for SME operators or manufacturers of the candidate energy conversion plants. With the help of the key parameter models, operators of small and medium size energy conversion plants can carry out the required LCA within a few hours. At the same time they can check whether the plant fulfils the "naturemade star" threshold or not. The threshold for e.g. electricity is set to 50% of the environmental impact in Eco-indicator 99 (hierarchist) points of a gas combined-cycle power plant.

The labelling scheme for electricity was introduced in 2001 by the Association for Environmentally Friendly Electricity (now Energy) (VUE) (Frischknecht & Jungbluth 2000). A new project has revised the key parameter models of several energy systems and allows now a labelling not only of electricity, but also of heat, refrigeration and biomethane. Furthermore the new key parameter models include a declaration of environmental impacts (GWP, cumulative energy demand, Eco-indicator 99 (H,A) points and ecological scarcity 2006) for all products delivered by the energy plant (Jungbluth et al. 2010b).

The VUE is financed through producer associations and by public funding. Important decisions are taken jointly by a steering committee consisting of the producers, government, environmental and consumer NGOs. The certification of individual plants is done in cooperation with external certification organisations.

3.3.5 Criteria for Energy Efficient and Low Emission Vehicles (KeeF)

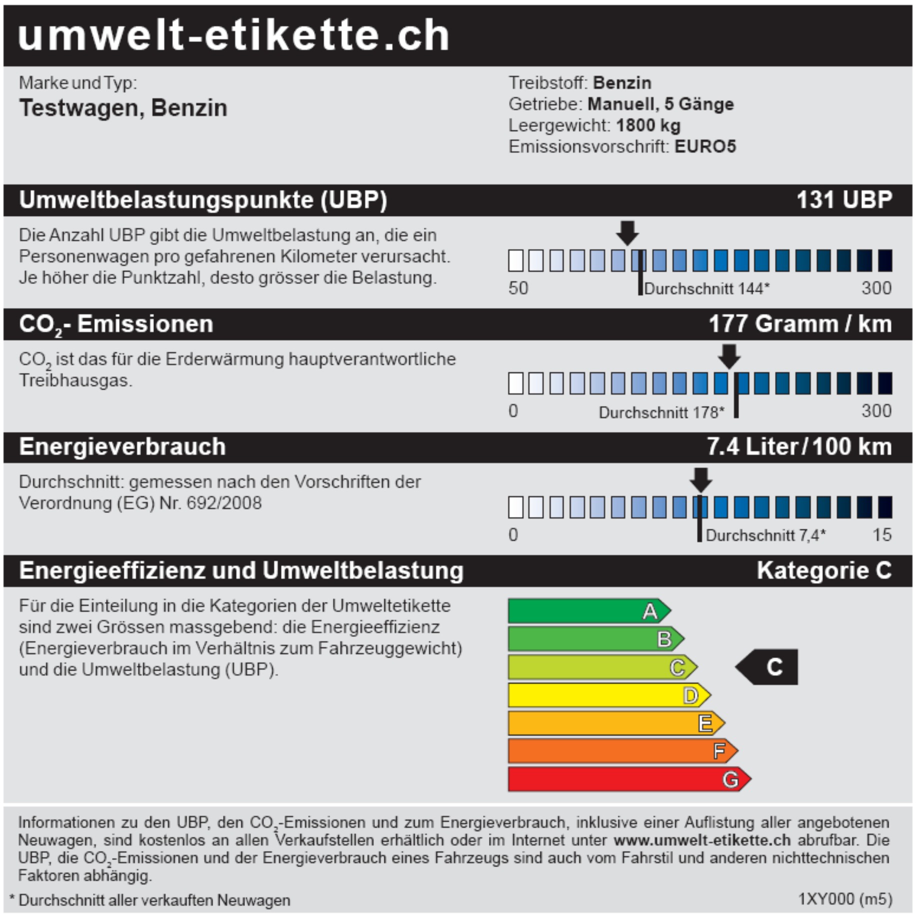
A joint project of different Swiss Federal Offices developed a set of criteria for the environmental assessment of passenger cars (KeeF). It was proposed to consider climate, air pollutants and noise from operation of the cars as well as the fuel production. Environmental impacts of fuel production were to be considered with generic data for different types of fuels.

It was proposed to declare these environmental impacts on the compulsory information for passenger cars with the aim to increase the share of energy efficient and low-emission cars in Switzerland. The ecological scarcity 2006 method was to be used for the impact assessment. Since 2007, a draft version of the KeeF has been in a test phase, but implemenation could not be completed.

The approach was a first step towards environmental information about this type of products. But it did not take into account the full life cycle (it excludes car production, maintenance as well as disposal). It might be arguable whether road infrastructure should have been included as this would not differ between different cars.

[16] Industrial and commercial public agency, under the joint supervision of French Ministries for Ecology, Sustainable Development and Spatial Planning (MEDAD) and for Higher Education and Research.

Fig. 3.1 Umweltetikette for cars (draft project example)



3.3.6 Construction List

The Coordination Conference of Construction and Property Institutions of Public House Builders gives recommendations for sustainable construction of buildings which include a list of life cycle assessment data of materials, processes and energy important for the construction sector (KBOB 2009). The life cycle assessment is carried out by applying the method of Ecological Scarcity (Frischknecht et al. 2009b) and by the calculation of cumulative greenhouse gas emissions and cumulative energy demand. This list is considered as a planning instrument for architects and civil engineers in the construction sector. It is not a label with certain recommendations, but more as a declaration of environmental impacts for different types of average market products for the building sector.

Source: *www.bbl.admin.ch/kbob/00493/00495/index.html?lang=de*

3.3.7 Other approaches covering several environmental aspects

Efficient Consumer Response (ECR) (AT)

Efficient Consumer Response (ECR) Austria is a communication platform of Austrian companies in the consumer goods industry with the aim to optimise their supply chain in order to serve consumers more efficiently. Similar communication platforms are operating in other European countries. The ECR working group for sustainability aims to develop a broad, standardised methodology for measuring the ecological sustainability of a product with the underlying vision of a voluntary product declaration that informs the consumer about the sustainability quality of products.

In a pilot study, the environmental impacts of an energy saving lamp and a light bulb were assessed. Production, packaging, transportation, and use phase were considered in the analysis. The impact assessment methods Ecological Footprint, Carbon Footprint, Ecological Rucksack, and Water Rucksack were applied. So far it is not clear whether a weighting will be applied. For all indicators, the results were dominated by the use phase of the two lamps.

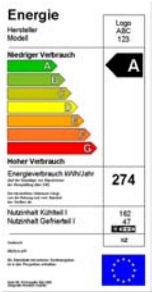
Source: *www.faktor10.at/sites/default/files/ecr_factsheet.pdf*

Blauer Engel (DE)

The “Blauer Engel” (Blue Angel) label marks products with an environmental benefit for one of the four defined protection goals: protection of health, climate, resources, and water. The label is not based on LCA, but on product specific environmental requirements that are developed by the German Federal Environment Agency (Umweltbundesamt, UBA). For example, equipment carrying the label “Blauer Engel; protects climate” needs to have low energy consumption. Regulations for one hundred climate relevant product groups are planned. As of now regulations for nine product groups are implemented.

Source: *www.blauer-engel.de*

Energieetikette (CH)



The energy use of white goods and further properties of the product are shown on the “Energieetikette”in Switzerland since January 2002. This is partly based on the Energieverordnung ordinance and further EU regulations. The etiquette shows the energy use compared to the average of all products sold. This is differentiated for different classes ranging from A to G with A (green) being the most efficient appliances. Electricity use is also stated in kWh.

Here the definition of product groups might involve some important implications for comparability. Thus a product with a good ranking is not necessarily also a good product if compared on a functional scale. E.g. for a buying decision on a refrigerator one should also consider the size one really needs in the household and not buy one that is too large. Or for a car it might be important how many persons can be transported and how many are transported on average.

Source: *http://www.bfe.admin.ch/energieetikette/*

3.4 Carbon labels

Two Swiss discussion forums on LCA dealing with aspects of CO_2 labels were held in the last two years. Information given on these workshops has been one basis for elaborating the following chapter.

Source: *http://www.lcainfo.ch/df/DF34/Program.htm*, *http://www.lcainfo.ch/df/DF37/Program.htm*.

A summary of global carbon labels has been elaborated by the ClimateChangeCorp.com, which is an independent news website: *http://www.climatechangecorp.com/s/carbon-labelling-report-thanks.asp*

3.4.1 Carbon Footprints

Carbon footprint labels look at the greenhouse gas emission over the life cycle.

ISO standard 14067

ISO standards for carbon footprints of products (ISO 14067, International Organization for Standardization (ISO) 2009) and their communication are currently under development and will be finalised in 2011.

Greenhouse Gas Protocol Product/Supply Chain Initiative (GLO)

The World Resource Institute and the World Business Council for Sustainable Development are currently developing a new standard for product and supply chain greenhouse gas accounting and reporting. To develop the new guidelines, the GHG Protocol is following a broad, multi-stakeholder process with participation from businesses, policy-makers, NGOs, academics and other experts and stakeholders.

The new GHG Protocol guidelines will provide a standardised method to inventory the emissions associated with individual products across their full life cycles and of corporate value chains, taking into account impacts both upstream and downstream of the company's operations. By taking a comprehensive approach to GHG measurement and management, businesses and policy-makers can focus attention on the greatest opportunities to reduce emissions within the full value chain, leading to more sustainable decisions about the products.

The parts of the standard covering the life cycle inventory analysis follow as far as possible ISO standards for LCA, carbon footprints and the PAS 2050.

Source: *http://www.ghgprotocol.org/standards/product-and-supply-chain-standard*

Climatop (CH)

Climatop is a Swiss product label that declares "climate friendly" products. Products are considered as "climate friendly" if they emit at least 20% less CO_2 than other products from a predefined reference group. In addition, the product has to fulfil several other requirements regarding environmental and social standards.

The calculations are done by a non-governmental organisation and are financed directly by the producer who wants to get the label. A critical review by a second organisation approves the quality of the underlying LCA. There are some basic rules published in June 2009. But no clear rules are available, for example about the definition of product categories, the choice of alternatives or the inclusion of the use stage. Such rules are decided on a case-by-case basis. Thus, for example for the first product category – washing powder – only products sold by one retailer have been included in the analysis. For labelling a hand-drying system, several market products are taken into account. By August 2009, 11 product groups had been labelled, including washing powder, hand drying systems, asparagus, sanitary papers, sugar and others.

Source: *www.climatop.ch*

Carbon Reduction Label and PAS 2050 (UK)

The Carbon Reduction Label is a consumer label for products and services. It has been developed by the Carbon Trust. The Carbon Trust is an independent company set up by government with a mission to accelerate the move to a low carbon economy in the UK. It is funded by different governmental organisations, but gets also a part of funding through private paid projects. The total budget amounts to more than 100 MM pounds. The Carbon Trust has two wholly-owned commercial subsidiaries involved in providing accreditation services: the Carbon Label Company Limited and the Carbon Trust Standard Company Limited.

Labelled products are for example sold by the supermarket chain Tesco. The Carbon Reduction Label is compliant with PAS 2050 (Carbon Trust & DEFRA 2008), the Publicly Available Specification document for assessing the life cycle greenhouse gas emissions of goods and services in the UK. In August 2009 17 companies were working with the Carbon Reduction Label, having 23 products certified, such as textiles, bank accounts, food, drinks, etc.. For some of these products the GHG emissions from different consumer behaviour were calculated. For example the Carbon Reduction Label on washing agents declares that " washing at 30°C rather than 40°C saves 160 gCO_2 per wash".

Even though the Carbon Reduction Label and the PAS 2050 are based on the British Standard model, they are widely accepted by industries and scientists in other countries. The PAS and the corresponding guide give detailed and helpful guidelines on how to perform an LCA, concentrating on GHG emissions but neglecting other environmental impacts than climate change.

Sources: *http://www.carbon-label.com/*
http://www.bsigroup.com/en/Standards-and-Publications/How-we-can-help-you/Professional-Standards-Service/PAS-2050/

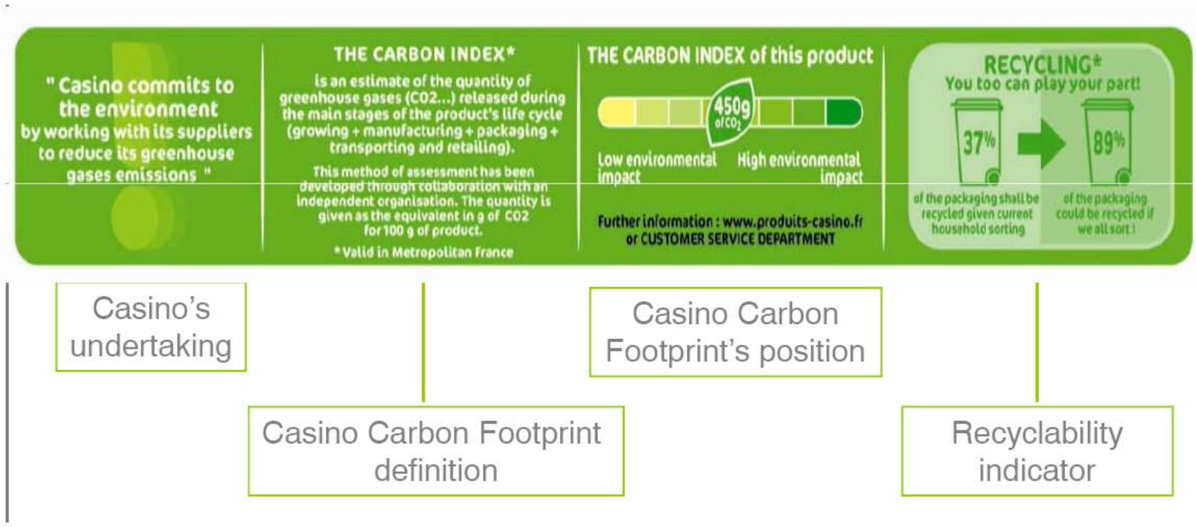
Indice carbone Casino (FR)

The "indice carbone" label created by Casino supermarkets in France shows the CO_2 emissions of 3000 food products sold in Casino stores. The CO_2 emissions are calculated on a cradle-to-gate approach using a model developed by bio intelligence services Ltd. The establishment of this model was partly financed by ADEME, the French environmental agency, and therefore the model is based on data provided by ADEME.

The model covers the agricultural production, all transports, food processing, packaging and storage at the supermarket. The label shows the CO_2 equivalents emitted for 100 grams of product on the product and the shelf.

At the back of the packaging, a seven-tier ranking system shows the overall environmental impact of the product, which is calculated on the base of the carbon footprint. Furthermore, the recyclability of the product is shown in a forth pictogram (Fig 3.2). In order to calculate the Carbon Footprint of the products, Casino provides a software program to the suppliers, in which they enter the data relevant for the Carbon Footprint calculation. The review process of data collection by the suppliers is not described.

Fig. 3.2 Further explications of the Carbon Footprint depicted at the back of the packaging (Picard 2008)



Source: *http://www.produits-casino.fr/vos-marques/developpement-durable.html*

Carbon Footprint Label (KR)

The Korean Carbon Footprint Label is an end consumer product label with a legal background. The purpose of the Label is to promote a consumer-led purchasing pattern of low carbon goods and to encourage enterprises to develop technologies towards low carbon goods. It declares the amount of greenhouse gas emissions from the life cycle of a product and indicates the share of the different product stages.

Source: *http://www.edp.or.kr/carbon/english/*

Product Carbon Footprint Project – PCF (DE)

The Product Carbon Footprint project is set up in order to exchange experiences with the calculation of product carbon footprints and discuss the communication of the results and the labelling of products. Several research institutes and NGOs worked together in the project.

Within the project, fifteen case studies were accomplished in which the carbon footprint of consumer products and services were calculated. Beside the carbon footprints, other environmental indicators were also considered. The PCF members advise against a product declaration with an aggregated CO_2 value, due to large uncertainties and room for interpretation of the methodological background. The reports of the case studies are publicly available.

The PCF does not provide a methodology for carbon footprints, but gives recommendations for an international harmonisation of the methodology and the communication of results.

Sources: *http://www.pcf-projekt.de/main/product-carbon-footprint/*, *http://www.oeko.de/dokumente/090702_pcf_konf.zip* Grießhammer & Hochfeld 2009

Climate labelling for Food (SE)

The Swedish labelling system for food is under development. It should present good climate alternatives within each product category by setting measures the producers have to realise in order to reduce their impact on climate change. The standards include qualitative criteria and not an LCA. The labelling system covers the entire production chain for a product, where measures are taken that decrease climate change impacts. It covers both Swedish and imported products and is an additional labelling that only should be used combined with another certification that sets clear requirements on sustainability goals. The project reports are public.

Source: *http://www.klimatmarkningen.se/in-english/*

Carbon Footprint of Products (JP)

Japan has started its carbon footprint of products activities in 2008 and it has been actively engaged in international standardisation activities as a member of ISO/TC207/SC7/WG2. In the meantime, with high social awareness of greenhouse gas emissions in Japan, various domestic activities have been conducted including pilot projects for establishment of a carbon footprint programme and a study of its impact on a variety of stakeholders.

This approach is still under development but can be considered similar to the Carbon Reduction Label and PAS 2050.

Source: *http://www.jemai.or.jp/english/carbonfootprint.cfm*

3.4.2 Carbon compensation or carbon neutral labels

Special types of labels are those marking "climate neutral" products. Two labels of this type are presented and commented here.

By-air (Coop)

The Swiss supermarket chain Coop developed the "by air" label for products that are transported to Switzerland by air. Coop intends to reduce the amount of products transported by air and the same amount of CO_2 emissions generated due to the air transportation is to be offset in CO_2 reducing projects financed by the company's compensation fund. The development of the CO_2 reducing projects is accomplished with WWF.

The label is to provide consumers the possibility to recognise and avoid products transported by air-plane. Such products have in most cases considerably higher environmental impacts than products transported by ship (Jungbluth 2000) and so far it was difficult for consumers to recognise such products.

Source: *http://www.coop.ch/nachhaltigkeit/social/byair-de.htm*

Klimaneutral – climate neutral (myclimate)

The climate neutral label of myclimate declares that an organisation gives financial support to myclimate projects for reduction of CO_2 emissions. The same amount of CO_2 emitted by the labelled organisation or product is intended to be reduced in those myclimate projects. Therefore the polluter pays in order to support a project at the partner with the intention to achieve emissions reductions compared to what would have been emitted by the partner without such support.

Source: *http://www.myclimate.org/kompensation/label-klimaneutral.html*

Recommendations

The label "climate neutral" just shows that the producer has paid a certain amount of money to projects that aim to reduce GHG emissions elsewhere. From our the point of view, such a label does neither show a better nor a good product. Emissions caused in the product life cycle are not removed. Only the responsibility is shifted to another actor who might not be aware that they cannot claim anymore the benefits of their green production technology.

The idea of carbon trade as such is not criticised in general as it might help to provide financial funds for interesting and useful projects. It can support business decisions as it at least partly internalizes external costs. But, in our point of view, such projects can only be claimed as a green investment or green donation rather than neutralization. It should not be allowed to include such credits in the calculation of environmental product information.

3.5 Summary of approaches investigated

A summary of the labelling approaches considered in this study is displayed in a comparative table (Table 3.1 for environmental labels, Table 3.2 for carbon footprint labels). The same criteria as described in subchapter 3.1 are applied.

Tab. 3.1 Summary of main criteria for different environmental product information approaches investigated in this study

Approach	Product groups	Parts of the life cycle covered or neglected	Guidelines and methodology for inventory modelling	Impact assessment method used	Communication approach	Organisational aspects	External review and quality assurance	Transparency
Environmental Product Declaration (EPD)	All kinds of products and services. Metal, food, energy, wood, paper and plastics products, furniture, machinery, services etc. In August 2009 93 products had an EPD and 68 products had climate declarations.	Cradle-to-gate not including use phase.	The EPD programme instructions are described by the International EPD Cooperation in a report and are available online. Product category rules are developed jointly by interest groups.	Resource use, emission of pollutants and the associated potential environmental impacts (e.g. global warming, stratospheric ozone depletion, photochemical oxidant creation, acidification and eutrophication), and waste generation. It is possible to include other types of information as appropriate.	Mainly for business-to-business communication. But business-to-consumer communication is not excluded. Table with quantitative results for impact categories and selected pollutants and resources.	Producers are responsible.	Technical committee linked to the International EPD Consortium approves the report. Underlying data are externally verified.	Documents publicly available, underlying LCI may be confidential.
IMPRO - environmental IMprovement of PROducts (EU)	Only case studies: • passenger cars, (finished) • meat products (ongoing) • housing (ongoing)	All product stages included.	Internal	Acidification, toxicity, global warming, ozone depletion, etc.	Publication of case studies. No product specific communication.	European Commission Joint Research Centre; European Science and Technology Observatory; Institute for Prospective Technological Studies	-	-
Projet d'affichage environnemental dans le cadre de la loi Grenelle (FR)	Major consumption goods and services	Life cycle approach postulated. Parts with a negligible or marginal influence can be omitted. Consumption behaviour and end-of-life scenarios must be included if relevant.	First evaluation according to ISO standards 14040 or 14044. Further evaluation: for each product category individual modelling guidelines. Detailed guidelines will be established.	Currently no impact assessment methods defined. Indicators will be defined individually for every category of products.	The declaration should give quantitative information. Communication details not yet defined.	Producer is responsible for labelling. National organisations supervise data and database.	National coordination foreseen. Review processes not yet defined.	Postulated that database and calculations should be accessible to the public.
Efficient Consumer Response (ECR) Austria	Consumer goods. Pilot studies with lamps, spinach and mineral water.	Production, packaging, transportation and use phase.	-	Ecological Footprint, Carbon Footprint, Ecological Rucksack, and	So far only pilot studies. Product declaration for consumers is a vision.	Sustainable Europe Research Institute (SERI)	-	-

Approach	Product groups	Parts of the life cycle covered or neglected	Guidelines and methodology for inventory modelling	Impact assessment method used	Communication approach	Organisational aspects	External review and quality assurance	Transparency
				Water Rucksack.				
Blauer Engel (DE)	All products and services with an environmental benefit can be certified if product specific requirements are established. Planned: 100 climate relevant product groups Implemented: 9 groups	Is not an LCA, but demands compliance with product specific requirements. For example equipment with the label “protects climate” need to have low energy consumption.	The product specific requirements are developed by the German Umweltbundesamt. For some product groups reports about the development of criteria are available.	No impact assessment. Four subjects of protection: Climate Resources Water Health	End consumer product label with four different designs depending on the subject of protection	German Umweltbundesamt assists the development of criteria. A steering group comprising several stakeholders is involved in the development. The RAL Deutsches Institut für Gütesicherung und Kennzeichnung e. V. is the certification organisation.	Not always an external inspection required.	Product requirements are public.
Plant specific labelling of energy systems (naturemade star)	Energy systems producing electricity, heat, cold and biomethane	Cradle-to-gate not including use phase of energy carrier. Simplified inventory of key parameters in a model based on a detailed LCA.	Draft methodology report	Eco-indicator 99 (H, A) Environmental information with Ecological Scarcity 2006 GWP CED, non-renewable	“naturemade star” label for renewable energy can be shown by energy suppliers and end users of energy.	VUE is label holder. External company (ESU-services) developed LCA model. Plant owner provides data to certification companies (e.g. Swiss TS). Plant owner pays certification fee.	Steering group of technology experts. Certification organisation and VUE cross checks the data collected for energy plants.	Methodology and basic LCA reports published.
Kriterien für energieeffiziente und emissionsarmem Fahrzeuge (KeeF)	Passenger cars	Exhaust emissions of cars and fuel production.	-	Ecological Scarcity 2006 GWP CED	Product label: quantitative and qualitative (categories) information	Governmental offices and commissioned companies	-	
KBOB Construction list	Building materials	Resources, production and end-of-life are included, use phase and transportation to site are excluded.	Generic data according to the ecoinvent database	Ecological Scarcity 2006 GWP CED, non-renewable	List of environmental burdens from different materials published for technical experts in the construction sector.	A selection of governmental offices and external experts.	The list with recommendations is based on the ecoinvent database, which includes a review of the data.	Reports are publicly available

Tab. 3.2 Summary of main criteria for different carbon footprint labelling approaches investigated in this study

Approach	Product groups	Parts of the life cycle covered or neglected	Guidelines and methodology for inventory modelling	Impact assessment method used	Communication approach	Organisational aspects	External review and quality assurance	Transparency
Greenhouse Gas Protocol Product/Supply Chain Initiative	Consumer goods and supply chain. In principle it should be applicable to all types of products. No products certified yet.	Upstream and downstream including assumptions for the use and end-of-life phase. It is intended to define cut-off criteria for inclusion of inputs based on a threshold value, e.g. inputs contributing less than 5% of the final CF are excluded from the calculation.	Under development	CF	It is planned to show somehow the CF of the products to end consumers and business partners.	Under development	Under development	Under development
Climatop (CH)	All kinds of consumer goods, e.g. washing powder, cream, hand drying systems, crude cane sugar, toilet paper etc. In August 2009 13 products were certified.	Full life cycle, but the inclusion of the use and end-of-life phase is unclear. Sometimes use phase is a criterion (e.g. washing powder includes energy use of washing machine), sometimes not.	No published general guidelines. Decisions are made case by case and are thus not consistent. Problematic is a comparison with market products without involving all stakeholders.	CF, other impacts are screened with ecological scarcity 2006 but not reported.	Best of group (top-runner) is declared on product, at point of sale and on website.	NGO paid by one producer or retailer who wants to get the label. Calculations also outsourced to consultancy.	Review by third party paid by the NGO. Only stakeholders who pay are consulted.	Only results are published.
Carbon Reduction Label (UK)	All types of consumer goods. So far: drinks, light bulbs, crisps, shampoo, detergents, T-shirts, web saver account, potatoes, and paving products. In August 2009 23 products were certified.	Full life cycle: Raw materials, transportation, production, distribution, use, disposal. For use and disposal assumptions are made. Information of GHG emissions from different behaviour may be calculated.	Publicly Available Specification (PAS) 2050 Code of Good Practice for communication of results to consumers.	CF	End consumer product label with amount of GHG emissions from life cycle. Labels may show the consumers also how to reduce their own carbon footprint by preparing, using, washing or disposing of the product in the most efficient way.	Producer or outsourced to consultancy.	Carbon Trust Company. Independent certification.	LCA reports are not available online.

Approach	Product groups	Parts of the life cycle covered or neglected	Guidelines and methodology for inventory modelling	Impact assessment method used	Communication approach	Organisational aspects	External review and quality assurance	Transparency
L'indice Carbon Casino	3000 food products	Cradle-to-gate approach, including the transport to the customer: agricultural production, processing, transports and distribution. The use and end-of-life phase is not included	Guideline development was supported by ADEME. No guidelines public available.	CF	Front label showing GHG emissions per 100g of product to consumers. At the back reference scales of CF and information on recycling.	Software provided by Casino. Data sampling and entry by supplier.	Model reviewed by ADEME, but no information about review procedure for data sampling at the production site.	The homepage shows a rough outline of calculations.
J'economise ma planète (E.Leclerc)	All food products, some other consumer goods e.g. furniture, services, etc.	Full life cycle	Unknown	CF	Absolute value on the price label at the shelf and the total emissions of the purchase in kg CO_2 eq.	E. Leclerc Supermarket	Unknown	Unknown
Korean Carbon Footprint Label	All consumer goods excluding agricultural, fishery, livestock goods and medical equipment. Examples: flights, gas boilers, water filter, washing machine, wardrobe, shampoo, cola etc. In August 2009 35 products were certified.	Life cycle excluding production of energy using-products. Life cycle without use phase for non-energy using products.	Statutory basis. Korean EPD common standard, PAS 2050.	CF	End consumer product label with amount of GHG emissions from life cycle. Indication of impact from different stages and reduction commitment.	Producer	Results are verified by the Korea Eco-products Institute.	Only results are published.
Product Carbon Footprint Project – PCF (DE)	All kind of consumer goods. 15 case studies implemented.	Entire life cycle	ISO 14040/44	Focusing on CF in the case studies. Other indicators such as water consumption, human toxicity, eutrophication etc. are evaluated as well, but not communicated.	No communication of aggregated carbon footprints, but reports are publicly available.	Producer	Critical review foreseen	Case studies are publicly available.
Climate labelling for food (SE)	Only food products. Currently focusing on fruit, vegetables,	Production and transportation.	The standards will be based on existing LCA analyses	CF	End consumer product label. Good climate alternative	External certifier paid by the producer.	Certification by KRAV or Svenskt Sigill.	Standards documents are publicly available.

Approach	Product groups	Parts of the life cycle covered or neglected	Guidelines and methodology for inventory modelling	Impact assessment method used	Communication approach	Organisational aspects	External review and quality assurance	Transparency
	fodder, milk, cereals, fish and shellfish.		and the assembled knowledge on climate change impacts (with some additions) and will be worded as general standards that regulate activities impacting on climate.		within each product category is shown.	Only in combination with other certification that sets clear requirements on sustainable development.		
Carbon Footprint of Products (JP)	All kind of consumer goods.	Entire life cycle including use phase.	Detailed guidelines (draft version) by the Japanese Government.	CF	Amount of GHG emissions declared on the product.	Not available.	No external review is mentioned in the technical specification document.	The general principles and technical specification documents are available.
Energieetikette (CH)	Energy using products such as white goods and cars.	Direct consumption of electricity in the use phase.	Swiss law and EU regulations	Electricity use	Differentiation of seven classes (A-G) according to average of products sold on the market and absolute value in kWh.	Producer has to declare according to guidelines.	Swiss Federal Office of Energy can control.	Control and possible fines in case of missing or wrong information. Easy to measure with standard tests.
By-air (Coop) – CO_2-kompensiert	Consumer goods that are transported by air (mainly vegetables, fruits, meat and flowers) and whose GHG emissions are compensated in projects that are elaborated together with the WWF.	Air transport of the food product	-	CO_2 emissions from air transportation.	End consumer product label. No quantitative declaration for the individual product about the amount of CO_2 released.	Retailer Coop declares the transport.	None	Clear what is meant by the label if one knows the details. Might be misguiding if consumer think that compensation is a positive aspect.
Klimaneutral – climate neutral (myclimate)	Organisations, products or events whose GHG emissions are compensated by myclimate	Production and Transportation seems to be included. Use phase seems to be sometimes excluded.	Guidelines for LCI not known. It is claimed that CO_2 emissions are reduced before compensation as far as possible.	GHG emissions.	End consumer product label “climate neutral”. No quantitative declaration.	NGO (myclimate) paid by the company who wants to get the label.	None.	None.

3.6 Conclusions and recommendations from evaluating existing approaches

We have evaluated several approaches for environmental product information. In this section we summarise the main differences found according to the criteria set for evaluating the approaches as described in sub-chapter 3.1. This study focuses on environmental product information. Examples that aim to investigate and monitor environmental impacts on a regional or national level are not further considered.

As a general observation, most labelling approaches do not comply with one or several principles stated in the ISO 14020 document (see section 3.3.1). Hence, they have a potential to be improved with regard to international harmonisation.

3.6.1 Range of product groups covered

The different approaches differ concerning the range of products covered. Several approaches develop product category rules (PCR) in order to give further procedural recommendations for one specific type of products. This allows for good comparability within the product group, but not for comparability at higher levels of decision-making.

In our view, it does not seem feasible to use a general methodology for all types of products investigated over the whole life cycle, because there are too many aspects which would have to be taken into account. With PCR one is more flexible to concentrate regulation on issues which are really relevant for the specific product group while simplifying the approach as far as possible by setting aside issues which are known not to be relevant for this group. LCA case studies show that for each type of product different aspects might be relevant, such as transportation, packaging, specific emissions, models for emissions, aspects of the use stage, distribution, etc..

3.6.2 Parts of the life cycle covered or neglected

There are two issues to be considered: cut-off criteria and investigating parts of the life cycle that have to be forecast at the point of time when the environmental information about the product is elaborated.

Not much is known about the cut-off criteria applied in different labelling approaches. It seems that most at least try to model the life cycle without any defined rules for cut-offs. Cut-offs for certain parts of the life cycle lead to difficulties if one wants to provide information about relative differences between products (see annexe in Jungbluth et al. 2008 for more detailed explanation).

The second issue is more difficult to handle. The approaches differ considerably concerning the inclusion of the use and end-of-life phases and it seems to be one of the main challenges to describe clear guidelines for this in every approach aiming to provide environmental information about the full life cycle. Some labels only consider the life cycle from cradle-to-gate and thus only include the emissions until the point of sale. This allows drawing clear system boundaries, but might neglect important aspects of the life cycle. Other labels try to cover at least a part of the impacts attributable to consumer behaviour. This aspect is described in more detail in section 4.2.4.

3.6.3 Guidelines and methodology for inventory modelling

For a trustworthy approach, clear guidelines regarding methodology and inventory modelling are necessary. Agreement on a common database facilities the data collection. Some labelling approaches lack such guidelines. They seem to be decided more on a case-by-case basis.

3.6.4 Impact assessment method used

So far, most quantitative product labels use the carbon footprint (or energy) as an environmental indicator. Thus, only one relevant environmental aspect is considered. Experience shows that focusing only on carbon footprints might even direct developments in unfavourable directions from an environmental point of view (e.g. discussion on benefits of biofuels). Thus, accounting only for carbon footprints seems to be too limited.

3.6.5 Communication approach

The communication approach is highly important and depends on whether business-to-business communication or business-to-consumer communication is aimed at. The claim made on the product should be relevant and must be proven by the labelling procedure. Different approaches have been chosen by the investigated labelling approaches, e.g. providing quantitative information on the product, the shelf or the bill, labelling according to certain criteria, e.g. best-of-class, CO_2-compensation, below threshold limit, A being X% better than B, etc. Some claims provided by labels are not trustworthy e.g. a product being carbon neutral due to compensation payments or awarding a product “best of class” status although not all products were included in the analysis.

The goal of communication is to direct consumer choices toward more sustainable consumption. We have the perception that consumers ask for clear recommendations about the “best” product to buy and that they might have difficulties evaluating properties on a scale of impacts. Showing quantitative numbers seems to be more favoured by experts such as LCA practitioners. So far we do not know of a systematic comparison of different types of information and how they can best assist this goal. Thus, it might be advisable to investigate the possibilities of communication for changing behaviour before developing environmental product information.

3.6.6 Responsibility for the procedure

One can observe quite different approaches concerning the involvement of different type of actors in the labelling procedure. Typical actors directly interested are e.g individual producers, producer organisations, authorities, environmental NGOs or organisations directly founded for a specific labelling procedure. In addition, there are further actors responsible e.g. for calculation of environmental impacts and general certification organisations. Some labels are based mainly on an internal procedure by one producer or retailer. Thus, there is no involvement of external actors for methodology development, investigation of criteria and verification. On the other side, there are labelling procedures that clearly differentiate the roles of different actors and thus achieve a certain degree of independence between label provider and label user.

3.6.7 External review and quality assurance

The verification of the results is made by the label holder in most cases. This might lead to conflicts if the label holder also earns money by providing the label. So far, for many labels the procedure for dealing with possible conflicts is not clear.

3.6.8 Conclusions for a good approach

The following conclusions are drawn from our evaluation of a range of different approaches.

A good approach for environmental product information should include general guidelines as well as product category specific recommendations for investigating the use phase (where necessary). This is essential in order to take account of product specific issues to a degree that is necessary for coverage of all relevant aspects. This might lead to the constraint that specific guidelines for product groups allow for comparability within one product category but not between individual products from different categories. Summing up results for all products purchased is only possible if no double counting occurs due to inclusion of downstream activities.

It is necessary to clearly define the system boundaries with regard to the inclusion of the use phase and end-of-life treatment. A detailed description and first recommendations for dealing with different stages in the life cycle can be found in section 4.2.4.

Clear communication guidelines for the provision of environmental product information are necessary in order to avoid a biased approach.

It is not sufficient to take into account only one indicator as carbon footprint for environmental information for products. Product information should encompass environmental impacts as far as scientifically possible. Therefore it is necessary to apply an LCIA method that covers several environmental aspects without omitting any necessary information in the LCI.

We recommend better investigating the different approaches for providing information on the product. This necessitates striking a good balance between simplicity and guidance for ready understanding by consumers on the one hand, and accuracy that can reflect the complexity of such information on the other. Further systematic research on the acceptance of such information by consumers may be necessary.

There should be a clear scheme for the responsibilities of providing environmental product information. At least one of the bodies involved needs to be fully independent from the company or producer who wants to show the information. This can be ensured e.g. by governmental financing or by financing the procedure through producer associations which have a group of members paying to an independent organisation. The following actors need to be distinguished:

- Who wants or needs to show environmental information on their products?
- Who provides life cycle inventory data for the different process stages?
- Who does the necessary calculations of key environmental numbers in an LCA?
- Who develops the methodology for investigating the environmental impacts?
- Who reviews and controls the process?
- Who pays for data investigation, impact assessment and review?

It seems to be necessary to have at least two different independent organisations for these aspects:

1 One organisation developing the methodology as well as reviewing and controlling the process. It might be better if this organisation is not financed directly by the producer, but by public funds or producer associations. This organisation (or a third one) might also establish and maintain a common database with LCI background data.

2 One organisation that does the calculations (this can be the producer or e.g. a consultant paid by the producer) and provides the information. This organisation should be fully independent from the one which controls the calculation process.

The first organisation should take responsibility for developing the PCR and certifying the information. Public authorities should play an important role within this organisation. Background data and data of common interest should be stored in one central database, preferably building on the ecoinvent database. Calculations for environmental product information can be done by companies or consultants and are commissioned by the producer of the product. Results should be reviewed by the controlling organisation.

A good environmental product information should include a broad discussion of the methodology with different stakeholders and a critical review of the calculations performed for the label. The process should be transparent and reproducible. There should be an independent body to deal with conflicts between different producers and diverging interests.

After evaluating these different examples, the question is now what is good environmental product information?

In short, a good statement should be:

- Truthful, accurate and able to be substantiated
- Provided by an organisation independent from the producer and in a clearly defined procedure
- Relevant
- Clear about the environmental issue the claim refers to
- Easily understandable for the target group (i.e. consumers)
- Explicit about the meaning of any symbol

3.6.9 Distinction from "greenwashing" approaches

On the other side, there are many bad examples of environmental claims made for products. Moreover, the following sins must be avoided:[17]

- *The Sin of the Hidden Trade-off, which occurs when one environmental issue is emphasised at the expense of potentially more serious concerns.*
- *The Sin of No Proof. This happens when environmental assertions are not backed up by evidence or third-party certification.*
- *The Sin of Vagueness, which occurs when a marketing claim is so lacking in specifics as to be meaningless. "All-natural" is an example of this sin.*
- *The (new) Sin of Worshipping False Labels. This is when marketers create a false suggestion or a certification-like image to mislead consumers into thinking that a product has been through a legitimate green certification process.*
- *The Sin of Irrelevance. This sin arises when an environmental issue unrelated to the product is emphasised. One example is the claim that a product is "CFC-free," since CFCs are banned by law.*
- *The Sin of Lesser of Two Evils, which occurs when an environmental claim makes consumers feel "green" about a product category that is itself lacking in environmental benefits. Organic cigarettes are an example of this sin.*
- *The Sin of Fibbing. This is when environmental claims are outright false.*

[17] Summary based on a presentation by Beatrice Bortolozzo, 2B consulting, Italy.

4 Life cycle assessment (LCA) methodology for environmental product information

4.1 Introduction

The method of life cycle assessment (LCA) (see section 2.4.1) is recommended for the environmental evaluation of consumer products. The LCA approach developed for the environmental product information should be elaborated according to ISO standards 14040 ff.. Now we elaborate these aspects, which are of special interest for the possible guidelines of a product label.

4.2 Goal and scope definition

Within the goal and scope definition of an LCA the underlying research questions and system boundaries are clarified. Here we focus on some specific aspects which are relevant for the development of a product label.

- Goal of the LCA for environmental product information (see section 4.2.1)
- Functional unit used for information about the product (see section 4.2.2)
- System boundaries (4.2.3) and distinction of life cycle stages more or less influenced by the producer (Production, distribution, delivery, use phase, end-of-life treatment) (see section 4.2.4)
- Aspect of data quality (see sub-chapter 8.3)
- Definition of product category rules (see sub-chapter 8.3)

4.2.1 Goal

The goal of an LCA study shall unambiguously state the intended application, the reasons for carrying out the study and the intended audience, i.e. to whom the results of the study are intended to be communicated.

For environmental product information, it might be more difficult to describe a specific goal. The information might address several levels of decision-making as outlined in Table 2.4.

4.2.2 Functional unit and reference flow

The functions of the investigated system shall be clearly defined. Products or services are defined as a functional output. The functional unit is a measure of the performance of the functional outputs of the product system. The reference flow is a measure of the outputs from the product system that are required to fulfil the function expressed by the functional unit.

For environmental product information one focuses on products or services as a functional unit. But the functional unit in a shelf might be defined in different ways. The environmental impacts can be shown per kg of product, for a usual function of the product e.g. one dose of washing powder for a washing machine or per value (CHF) of a product. Depending on how this reference unit is chosen it will influence the possibilities of consumers to use the information for different types of comparisons. Even for one product, it might make sense to define different functional units depending on the DML addressed and the decisions to be supported with the environmental information.

4.2.3 System boundary and cut-off rules

The system boundary defines the unit processes to be included in the product system. In many cases, there will not be sufficient time, data, or resources to conduct a fully comprehensive study. According to ISO 14040 several criteria are used to decide which inputs to be studied, including a) mass, b) energy, and c) environmental relevance. Any decisions to omit life cycle stages, processes or inputs/outputs (cut-off) shall be clearly stated and justified. The criteria used in setting the system boundaries dictate the degree of confidence in ensuring that the results of the study have not been compromised and that the goal of the study will be met.

We recommend discouraging the use of cut-off criteria for certain life cycle stages that are considered insignificant. Instead, it should be encouraged to use at least rough assumptions for the LCI for all inputs and outputs in the life cycle. Thus, e.g. infrastructure of buildings can be estimated with the generic data available in the ecoinvent database.

The geographical scope of the modelling is also an important issue. For example, an EPI developed for Switzerland would assume e.g. Swiss electricity mixes for electricity consumption during the use phase. But, with a European scope, environmental impacts would have to be calculated with a European electricity mix.

4.2.4 Life cycle stages in modelling of product information

For the environmental product information, it seems to be important to differentiate the influence of the producer of a product on its different life cycle stages in the setting of system boundaries. In practice, the producer or the distributor and not the end user would be responsible for calculating the environmental impacts of the product. Thus, for full life cycle thinking, assumptions have to be taken concerning the distribution to the end use, the use phase and the end-of-life treatment. Impacts from these phases depend partly on the product, but also partly on consumer behaviour. The following stages of the life cycle have to be distinguished:

Production

The producer has full responsibility for this process and oversees its environmental impacts. Packaging is usually also decided during this process and can be included in the analysis. Normally the producers can provide reliable data about the production of their products.

Distribution and retail

This involves transportation from the producer to the point of sale and environmental impacts in the distribution chain e.g. losses, energy use for refrigeration, etc. Distribution will be in the responsibility of companies being not the same as the producer. The producer has some influence on the impacts e.g. by contracting the transportation. On the other side differences may arise for the same product depending e.g. on the distance to the distributor or the means of transport. Sometimes it might be better to give the responsibility for environmental product information to the retailer as they have fuller knowledge of these aspects than the producer does.

Delivery

The responsibility for delivery is sometimes assigned to the consumer and sometimes to the distributor (e.g. furniture, fuels). The type of product can influence the environmental impacts of delivery. Thus, e.g. a single bottle of beer can easily be carried home by bike while a crate of beer will usually be transported with a car and might even be the argument to use the car. Some distributors offer systems to deliver the products to the home, which might be more efficient than private car transports. Large supermarkets outside the town centres are mainly attractive for car users and thus have an influence concerning the environmental impacts of the products sold there. Thus on the one side it might be argued that the delivery should not be accounted for in the environmental product information of the product and is more an activity on its own e.g. considered e.g. by direct environmental information for the transport mode. On the other side, there are clear interdependencies between weight and size of the product as well as point of sale to the impacts caused here.

Use phase

This includes energy use while storing, using or preparing the product as well as direct emissions e.g. from fuel burning or use of detergents. Losses e.g. of food in the household might be influenced by the conservation or packaging. For some products the usage time might be important, e.g. cell phones. The producer and distributor can oversee only part of the possible implications. Thus, e.g. an energy efficient appliance should use less energy in the household, but inefficient consumer behaviour might lead to higher impacts. Direct emissions of a car are predicted by the technology, but driving behaviour and frequency has also an influence. The packaging might influence losses in the household. It is normally not possible to recognise the full consumer behaviour while elaborating the EPI for the product. Thus, assumptions are necessary. They limit the validity of the EPI.

A further aspect is double counting and assignment of impacts to a certain product. Some washing powders got a label mainly because they can be used for washing at 20°C temperature and thus less energy is used for water heating. However, many households do not have such a washing machine or do not use it at the low temperature. Thus, it would make more sense to provide the label for such a washing machine and not for the washing powder.

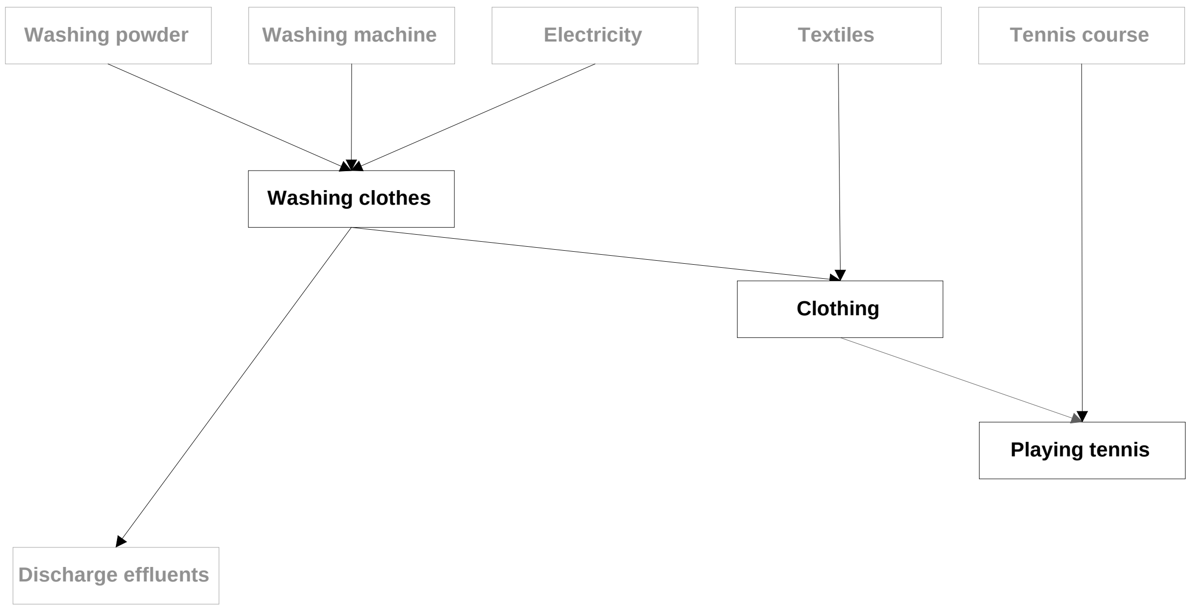
The problem of considering the use phase is further elaborated in Fig 4.1 for different degrees of influence by the producer. Grey boxes stand for products which are bought by the consumer. The environmental impacts of producing this product are directly under control of the producer. Black boxes describe consumer behaviour in the use phase. Here only product properties (such as energy efficiency) can influence the environmental impacts.

Now the question is what to include in the use phase of a certain product. It seems to be necessary to include for washing powder and washing machine also the direct inputs of electricity and the discharge of effluents in a life cycle evaluation (inputs of first-degree). On the other side, it does not seem necessary to include washing in the use phase of electricity, because electricity can be used in quite different ways and the individual product does not have a direct influence on this.

Washing is an important aspect in the life cycle of clothing. Thus also indirect inputs such as the buying of washing powder, washing machine and the electricity used during washing have to be considered if one wants to show the environmental impacts of different types of textiles over the full life cycle (second-degree inputs).

If one has to decide between different types of sport courses, clothing might have some importance in the use phase of this service again. Thus, diving and playing tennis can only be compared if the necessary equipment is included in an analysis. Therefore, the influence of washing powder has also to be taken into consideration (inputs of third-degree).

Fig. 4.1 Different degrees of influence in the use phase (grey – products, black – use phase with household activities)



In general, it can be said that if the use phase of a product involves in parallel a second product there will be double counting of environmental impacts because they are considered within the EPI of both products. We see three principles of including the use phase, which are outlined in Table 4.1 for the example of energy use. The principle could also be used for another input product, e.g. washing powder. This has an own life cycle but it is also used in the life cycle of the washing machine or the clothing. In reality it will be difficult to follow the principle of accounting for direct energy uses (or other inputs) in the use phase and it would be less accurate for a total balance than the strict consideration of all products until the basket of the consumer. This is the reason for our general recommendation not to include the environmental impacts of the use phase in the EPI of all products.

Tab. 4.1 Possible principles for including energy consumption in the use phase of products

Relation between energy and the product	Energy is the product	Energy is used directly for the operation of the product	Energy used by products which are used in the life cycle of the product under consideration is also included.
Degree of influence	No consideration of use phase inputs.	Inputs of the first degree	Inputs of the second or more degree.
Principle	The energy use during the product use is not considered. Energy provision is seen as a product on its own and impacts are only labelled when energy is sold, e.g. per kWh of electricity or per litre of fuel. For fuels it must be decided if emissions due to burning are included with the fuel or with the device using it. Thus, it will not be possible to consider the energy use for differentiation of products.	Use phase includes only the energy consumption of energy using products. These are products that need energy for operation and have a plug, a tank or another direct connection to an energy supply (e.g. cooking stove, lamp, refrigerator, car, heating). Emissions of burning fuels are considered as well.	The use phase includes all energy uses and direct emissions which are important in the life cycle of a product. Thus, e.g. in case of frozen lasagne, energy use by white goods for refrigeration and heating is included in the environmental impacts calculated for the lasagne.
Double counting	No double counting.	No double counting for energy using product if rule laid out in this column is strictly followed. Impact of energy provision is only accounted for the product that uses the energy, which is less accurate for the total balance. Different sources of energy (e.g. biofuels) cannot be labelled directly if double counting (with energy provision and energy using product) should be avoided. The impact of energy provision can be considered only once for the product directly using the energy if one wants to avoid double counting in a total balance. This would be less accurate for the total balance than directly considering the EPI of the energy product purchased (e.g. the total amount of electricity).	Double counting is part of the system. E.g. impacts of electricity provision for a washing machine are included in the EPI of electricity products, washing machines, washing powder and clothes, because for all these products the energy use is an important aspect in a life cycle perspective.

End-of-life treatment

Usually producers or distributors can give recommendations for correct or best end-of-life treatment. They can also design products in a way that supports low impacts at the disposal stage e.g. no material compounds, but easy to recycle one-material products. But they will not be able to control it as long as they do not offer a clearly organised take-back system. The end-of-life treatment might have important implications regarding environmental aspects especially if improper disposal routes such as littering or burning in stoves are chosen by the consumer. It is not only relevant for solid wastes, but also for emissions due to the discharge of effluents while using detergents. It might even be seen as relevant for end-of-life of products such as medicines, which end up in the sewer.

A label should clarify the recommended disposal routes and outline impacts of improper consumer behaviour.

Indirect effects of the product

The issue of including the use phase becomes even more complex if one intends to include indirect effects of the product. An example are insulation materials which would help to reduce environmental impacts due to heating. It might be argued to include these benefits within the EPI of the insulation materials. Therefore several more issues have to be considered, e.g. what is the reference value to which we compare and what type of heating is assumed for the building that is insulated with the material. Including such effects would lead to more complex issues to be solved in PCR.

Conclusion

The question of system boundaries for these phases which occur downstream of the point were the EPI is calculated could be difficult to solve and there is no perfect solution. We see two principal options: “at shop” or “at grave”, which both have also severe disadvantages. The main aspects are summarised in Table 4.2. The environmental product information should at least provide recommendations on important aspects of consumer behaviour if it only deals with the life cycle until the shop.

Within this study, we have to decide which of the different ways to follow even if there is no perfect solution. We recommend at the present point of time to restrict environmental information for products to the impacts associated with its production at the point of sale. We came to the conclusion that it is not feasible to provide EPI for the full life cycle for all products where the use or disposal stages might be relevant if one considers all disadvantages identified in Table 4.2.

Nevertheless, if one wants to follow a “full life cycle” approach as defined at the beginning of this study, we recommend to show second information for those products for which the use phase is relevant. While the first information e.g. for a car is provided for the product as it is bought (production of one car), the second information shows the environmental impacts over the full life cycle. This would include for a car the environmental impacts per kilometre driven accounting for the fuel production, associated emissions, production and disposal of the car. The details have to be defined in specific product category rules and thus the workload would be considerably higher than for products which are investigated only for the life cycle until the shop. Often it will not be possible to clearly identify which aspects belong to the use phase and which not.

In some cases an EPI only for the product at the shop might be misleading for direct comparisons with products with a similar function. Therefore the review process in the organisation should have the possibility to withhold such information and search for a solution.

Tab. 4.2 Main options for general system boundaries

Criteria	Cradle to point of sale	Full life cycle
Principle	Analogous to price. Environmental impacts are considered until the point where the product is sold to the customer. The price of the product and environmental impacts follow the same principle.	The full life cycle should be considered. This might include secondary products which are needed in the use phase (e.g. electricity for the washing machine) and direct emissions
Advantages	Principle is quite clear and does not leave much room for interpretation. Allows to add up total impacts of consumption. Good guidance on higher levels of decision-making. Directly related to reduced environmental impacts achieved in the production chain. One information can be used for comparison with all other products and many possible decision situations. Consistent with e.g. organic or fair trade label, other product information (e.g. nutritional value) and price information. A second information still could be provided in case the use phase is relevant.	Good guidance for the comparison of single similar products in a predefined setting for the decision-making. Possibility to include important aspects of the use phase. Highlights the importance of full life cycle thinking.
Disadvantages	For comparison of single products one might derive wrong conclusions if parts of the life cycle are neglected. Consumers have to think themselves about further aspects in the life cycle e.g. the washing machine that had low impacts during production, but higher electricity consumption during use.	Several difficult questions of how to handle distribution, use phase, end-of-life. Often it is not clear which product really determines the impacts in the use phase. Variation in consumer behaviour can have a large influence that cannot be fully considered. Functional unit must be clearly defined and thus the result is only valid for a very limited scope of decisions. Not possible to add up impacts of different products to one total figure because of double counting of inputs. Not appropriate for higher levels of decision-making as several double counting will occur. Product design or clear description must ensure forecasted benefits. Aspects influenced directly by the producer get less important which limits the influence of EPI on the reduction of environmental impacts during production. High workload for elaboration and discussion of product category rules. High influence of decisions in the development of PCR for product comparisons and thus difficult discussion with pressure groups and stakeholders. It does not seem feasible to develop clear guidelines and rules that can be easily applied.

4.2.5 **Product category rules**

The full goal and scope for labelling of certain product groups in the framework of an EPD is often defined in product category rules (PCR). Product category rules are a form of guidance and rules for the collection of data and other information, and for which method environmental impact assessment is used and how this information should be presented. As such they can be seen as part of the goal and scope definition as it is defined in the ISO standards for LCA. Some aspects covered in PCR are for example:

- Functional unit
- System boundaries of the modelling
- Background data used
- Allocation rules
- Cut-off rules
- Emission modelling
- LCIA methods used

Generally, each product that is unique should have an own PCR, this would in theory lead to a plethora of different PCR documents. Work with PCR, can be simplified when product groups have the same raw materials inputs, composition, types of components, etc., and thus the same set of general rules can be applied to a large number of similar products. If no PCR exists for the product to be declared, interested producers would need to develop one. To assist that work a number of “ready-made” PCR modules describe the rules which apply for different product categories.

The PCR process should be carried out in an open process in which various stakeholders have the opportunity to comment. This is important to make the PCR documents of as high quality as possible. A prerequisite for the development is normally a detailed LCA investigating also some scenarios for the specific product group. This helps to understand the influencing factors. When all relevant comments are incorporated into the PCR it is approved and established by a technical committee.[18]

We see in the context of EPI the need for PCR mainly for products where the use phase is to be investigated. Further information about this aspect can be found in section 3.3.2.

4.3 Life cycle inventory analysis

The second stage of an LCA is the life cycle inventory analysis (LCI) or short inventory analysis. Clear modelling guidelines within the inventory analysis are important with regard to transparency and reproducibility of the results. In case of environmental product information challenges of inventory modelling go beyond the common LCA practice. The following issues are tackled in this sub-chapter:

- Allocation (see section 4.3.1)
- Distinction between environmental impact caused in the country where the good is consumed and elsewhere (see section 4.3.2)
- Modelling of carbon offsets and green electricity (see section 4.3.3).
- Data demands concerning background and foreground data (see section 4.3.4).
- Quality criteria applied on common background databases (see section 4.3.5)
- Uncertainties (4.3.6) and variation (4.3.7) of data
- Attributional versus consequential modelling (see section 4.3.8)

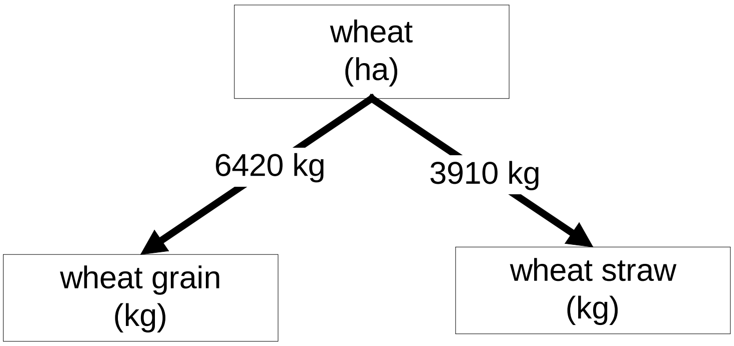
4.3.1 Multi-output processes and allocation rules

Introduction

Some processes do not only have one individual product output, but several outputs which usually serve different purposes. The planting of wheat used to make bread leads to two products: wheat grains and wheat straw (see Fig 4.2). During one year 6420 kg grain and 3910 kg straw are produced on average in Switzerland per hectare (Nemecek et al. 2007).

[18] Based on information provided on *http://www.climatedec.com/Create/howto/Product-Category-Rules-PCR/*

Fig. 4.2 Wheat production its co-products as an example of a multi-output process (data from Nemecek et al. 2007)



Multi-output processes are ubiquitous in LCA product systems. They are present in the energy industry (e.g., combined oil and gas production, oil refineries producing different fuels, combined heat and power production), in the mining industry (e.g., platinum group metals), in the chemical industry (e.g., phosphoric acid production), in forestry (e.g., sawing of timber), in the electronics industry (silicon purification with $SiCl_4$ as a by-product) and in particular in the biomass production systems (e.g., production of wheat and straw, production of soy been oil and soy bean meal, treatment of biogenic waste and production of biogas and compost).

Principles according to ISO 14044

The environmental impacts of the multi-output process have to be shared between the different products (allocation). The following stepwise procedure shall be applied according to ISO 14044 in the LCI (International Organization for Standardization (ISO) 2006b:4.3.4):

- *Wherever possible, allocation should be avoided by dividing the subprocesses to be allocated into two or more subprocesses and collecting the data related to these subprocesses or,*
- *Expanding the product system to include the additional functions related to the co products.*[19]

The ISO standard does not specify how the system expansion is to be performed. Two possibilities can be distinguished (see section 4.3.8 for further information):

- Expansion of the functional unit in order to investigate a basket of benefits in the systems under investigation.
- Subtraction of avoided burdens related to the co-products which are of no interest in the systems under investigation.

In principle there are two possibilities for the choice of the additional products or services included in the system while doing a system expansion:

- Average products and production of today are included (**attributional LCA**), or
- marginal products are identified and included (**consequential LCA**).

If allocation cannot be avoided the inputs and outputs of the system should be partitioned between its different products or functions in a way which reflects the underlying physical relationships between them.

[19] It is debatable whether this approach really avoids the allocation problem as stated by ISO. Frischknecht (1998) showed that this approach assumes a 100% allocation of benefits to the process of interest while other processes, which are not investigated in the foreground system, are burdened with the full environmental load of the process considered additionally by system expansion.

If physical relationship cannot be established the inputs should be allocated between the products and functions in a way which reflects other relationships between them. For example, input and output data might be allocated in proportion to the economic value of the products.

Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach.

Further details can be found in sub-chapter 8.1 of the annexe.

Conclusion

The ISO standard for the allocation procedure leaves a range of possible choices. These choices may have an important influence on the results and they involve subjectivity in any case. Choices related to allocation procedures need a careful explanation in any LCA. The choice of the approach is also dependent on the specific goals of the study. The rules for allocation for the environmental product information have to be defined in order to avoid a bias in the analysis of different products. To our experience, there are quite different points of view on this issue. Thus, even if it can be decided easily by one actor, it might involve considerable discussion about the approach with different interest groups.

We consider the approach chosen in ecoinvent v2.0 (Frischknecht et al. 2007b) as a good basis for the development of such rules. Approaches including avoided burdens or a system extension are not feasible in our view. We also recommend to clearly differentiate between two life cycles in case of recycling. Environmental impacts between the first and the second life cycle should be cut at the point were the material has no economic value.

4.3.2 **Direct and embodied emissions**

LCA normally takes a global view. Thus, within LCA case studies it is not evaluated in detail which part of the environmental impacts is caused in one country (e.g. Switzerland) and which part has been emitted elsewhere and imported as an embodied impact.

Such evaluations have been made for the total embodied emissions of Switzerland (Jungbluth et al. 2007c). Thus, there is some knowledge about the total embodied emissions in the case of Switzerland.

For individual products, such evaluation is quite time consuming and has to be done manually as it is so far not supported by the ecoinvent database or LCA software. Within the study on biofuels the share of GWP emissions within Swiss boundaries and outside has been evaluated (Zah et al. 2007: e.g. Abb. 37 on p. 43).

It is not feasible within a reasonable time frame to evaluate separately domestic and foreign environmental impacts for an EPI. So far, no databases or software tools exist to support such a goal. LCA has a global perspective and thus does not support thinking within national boundaries. If such a differentiation is intended it would be necessary to investigate all LCI data each time a different region should be distinguished. E.g. just separating between Swiss and other emissions in the ecoinvent database would involve the modelling of several hundred new datasets and the reworking of all 4000 existing datasets. Additionally it would need a further software development to allow a differentiated calculation of the results.

4.3.3 **Offsetting in the life cycle inventory analysis**

Some companies buy carbon-offsetting contingents and subtract the emissions offset from their total balance of environmental impacts. This is finally communicated with labels such as those described in section 3.4.2 or with some environmental product declarations which subtract compensated emissions from the emissions caused in the life cycle. Credits for carbon offsets are not allowed by some standards (e.g. Carbon Trust & DEFRA 2008).

In our opinion, no credits for carbon offsets should be allowed in the life cycle inventory for environmental information. In our view, such payments for carbon offsets should be seen as a donation rather than a real improvement of the physical balance.

The same applies e.g. to photovoltaic electricity production on a manufacturing site if this electricity is marketed separately. If the electricity used in the own production process, is purchased from the grid operator and PV electricity is sold, than environmental impacts should be calculated with the grid mix and not with the sold PV electricity.

Another situation occurs if the producer buys electricity or energy with a certain quality label. In this situation, environmental impacts should be calculated according to the environmental impacts caused by the specific mix bought and not with an average mix.

Thus, we recommend to generally calculate the environmental impacts of inputs in the life cycle with a quality label according to the economical relationships (to whom does the user pay to get the product?) in the first instance.

4.3.4 Background and foreground systems

Within the collection of life cycle inventory data, one can distinguish between background and foreground data and systems. Sometimes this is also referred to as the difference between site-specific and generic data or primary/secondary data.

Foreground system: The foreground system consists of processes which are under the control of the producer of the labelled product for which an LCA is carried out. Data from this operation are called foreground or primary data.

Background system: The background system consists of processes on which no or, at best, indirect influence may be exerted by the producer of the labelled product for which an LCA is carried out.

Background or generic data stem from public databases such as ecoinvent. The same data should be used in the environmental product information for all producers and all similar products. The production of these inputs in the life cycle is assumed the same for all labelled products. Typical examples are the electricity mix of a particular country, the impacts of providing fuels such as petrol, diesel or natural gas to a European customer, transport services and materials such as steel. These are products bought on an open market and it will not be possible for the single producer to trace back the origin of the crude oil used for producing petrol of a specific brand.

On the other side, there are product specific foreground data. These are specific data about the production of the labelled product, e.g. the amount of electricity used in the refrigeration of a ready-made lasagne. Foreground data are directly investigated or provided by the producer or by one of his suppliers. They are usually not taken from literature or public databases.

The more foreground data are used in the analysis the more specific is the result. Moreover, the better can a comparison between different products of individual producers be made. However, the more data have to be collected the higher will be the costs and efforts of such an analysis.

Foreground data have to be documented by the producer for the environmental product information process. Such data might sometimes be confidential and thus they can only be reviewed within a clearly defined process. For collecting and documenting such data, the same guidelines need to be used as for the background database (see section 4.3.5).

The definition of background and foreground data is strongly dependent on the product. Thus, e.g. if the product is electricity from a biogas plant, data about emissions and efficiency need to be site specific. If the product is bread produced with renewable electricity, it might be sufficient to use background data representing the electricity generation technologies while the actual electricity demand of the oven is part of the foreground data.

It is not easy to clearly define how much effort the producer invests in order to follow up the specific production chain of his products. Generally, site-specific data shall be used for the final production process that leads to the product under investigation. In case a distributor or retailer is responsible for the EPI, also the upstream production process has to be investigated site-specific. On a case-by-case basis, it might be necessary to investigate also foreground data for other upstream or downstream processes. In some labelling approaches data quality demand on site-specific and generic data are detailed in product category rules (PCR) (e.g. 2006; PCR CPC 17 2007). This should also be foreseen for the EPI developed in this study. The lower the DML is, the higher is the demand for site-specific foreground data.

4.3.5 Recommended background databases

In order to harmonise the work of the life cycle inventory analysis, it is necessary to provide recommendations concerning the background database that is used in the calculations. A major overview of LCA databases is available at *http://lca.jrc.ec.europa.eu/lcainfohub/databaseList.vm*. Table 4.3 compares some of the most important databases which would be applicable. Data quality requirements according to the ISO standard are described in sub-chapter 8.3 of the annexe.

We recommend using the current version of ecoinvent data (ecoinvent Centre 2009) as the prescribed background database. If generic data are not available for a specific input and no specific data are available from the supplier, the producer or the EPI holder should be responsible for providing such data to the ecoinvent database and have the quality controlled by the ecoinvent centre. Thus, it can be ensured that future analyses by the same or other producers will be based on the same assumptions. An example would be a chemical product used in production for which no specific data are available so far in the ecoinvent database and where the producer of the labelled product does not receive direct information from the supplier.

Tab. 4.3 Comparison of some LCA background databases

Name (of the database):	ecoinvent	ILCD	GEMIS	Probas	GaBi
Number of datasets	4000	300	10000	7000	2300
Which economic sectors are covered	Energy, transports, waste, materials, agriculture, etc.	Investigated in EU funded projects.	Energy (fossil, nuclear, renewable), materials (metals, minerals, food, plastics…), and transport (person and freight), as well as recycling and waste treatment processes. Monetary IO tables can be included for hybrid modelling	ProBas is not a data source itself, but rather a compilation, a “library”, of data from very different LCA sources.	All types of materials, energy carriers, services, and processing technologies
Regional focus	Switzerland, EU, Global	Europe	EU-27 countries for energy plus AU, CA, NO, RU, US, and various developing countries (BR, CN, IN, MA, MX, ZA).	Germany and GLO	GLO
Industry involvement?	Publicly available information and direct information from industry	Yes, direct data delivery	Mainly consultancy projects	Public industry databases	Industry projects and public industry data
Are cumulative data (LCI results offered?	Yes	Yes	No. Can be calculated.	Yes	Yes
Is unit process information provided?	Yes	Only for some parameterised processes	Yes	No	No
Are there restrictions regarding pollutants/resources reported?	No	No	Yes, mainly major air pollutants, other pollutants not systematically included	Mixed	No
Is infrastructure / capital goods manufacture included or excluded?	Included in all cases	Unknown	Partly included	Mixed	Unknown
Do the owner claim data consistency?	Yes	Yes	No	Not consistent, very different sources	Yes
Ability to judge the consistency of the database?	Yes	No	Yes	No	No
Are there any data quality indicators being used?	Yes	Unknown	Partly	No	Partly
Is there a description of data quality per dataset?	Yes in report provided as PDF.	In html sometimes generic for several datasets	Partly in reports available as PDF, partly only electronically. No conclusive documentation.	No	Generic information in html files for several data sets together.

Name (of the database):	ecoinvent	ILCD	GEMIS	Probas	GaBi
Is any uncertainty information available?	Yes	No	No, but foreseen in format	No	No
Is a particular data format used? If yes, what is (are) the name of the format(s)	EcoSpold based on XML, Excel, Html	Html, ILCD format based on XML	Gemis format, txt	Excel and PDF	Gabi-format
Who owns the data (industry, academia, consultants) and who provided the data?	ecoinvent Centre (research)	EU JRC (public)	Öko-Institut (NGO, consultancy)	Umweltbundesamt Deutschland (public)	PE International (private)
Are the datasets reviewed by an external / an internal reviewer?	By project partners from different organisation	Internal review by JRC	Internal	No	External by Ecobilan
Are there regular updates?	Yes	Yes	Yes	Not so far	Yes
Price of using the database	1800 Euro	free	free	free	Basic price for software plus extra charge depending on extension databases. Price not published.

4.3.6 Uncertainty considerations in LCI

Within the life cycle inventory of a unit process, the amounts of the inputs and outputs are described with single figures (the mean values). This quantitative description of the unit process includes uncertainty because the mean values are uncertain. In reality, there might be a difference between the value that has been investigated (or measured and reported) and the "real" value.

Different types of uncertainty are present in the life cycle inventory data of a process (Frischknecht et al. 2007b):

- Variability and stochastic error of the figures which describe the inputs and outputs due to e.g. measurement uncertainties, process specific variations, temporal variations, etc.
- Appropriateness of the input or output flows. Sometimes an input or output does not perfectly match with the input or output observed in reality. This may be due to temporal and / or spatial approximations. For instance, the electricity consumption of a process that takes place in Nigeria might have been approximated with the dataset of the electricity supply mix of the European network.
- Model uncertainty: the model used to describe a unit process may be inappropriate (using for instance linear instead of non-linear modelling).
- Neglecting important flows. Sometimes not all relevant information is available to completely describe a process. Such unknown inputs and outputs are missing in the inventory.

So far, there is no standardised procedure for how to document and analyse different types of uncertainties in the LCI. As a general experience uncertainties of LCI modelling are in the range of 10-20% at least. This means that differences in the results in the third or even second digit are normally not relevant. For environmental product information, such small differences need to be disregarded in order to avoid an unreasonable discrimination. Therefore, it is advisable to show rounded figures with only 2 digits or even only orders of magnitude of environmental impacts.

It has to be noted that the impact assessment introduces further uncertainties to the analysis which might be even more important than the inventory uncertainties. Different types of impact categories can be assessed with differing degrees of confidence. Thus, there might be biased consideration of products that cause problems to different impact categories. This, uncertainty will add to the uncertainty of data collection.

4.3.7 Variation of LCI data

A special problem for environmental product information might be variation of data in the life cycle of a product. Thus, e.g. many vegetables or fruits will be purchased over the year from different farmers, which might differ concerning the production patterns. This might also be influenced by seasonal variations or different natural condition. For sustainable consumption, it is necessary that consumers can recognise these seasonal variations. Thus, it is necessary e.g. for an EPI on tomatoes to revise the results each time something in the supply chain changes. However, this might impose some workload for the retailers for specific types of products where variation might be large. But only this makes it possible for the consumer to determine the best product at a given point of time.

Other variations might occur e.g. if suppliers in the supply chain are changed. For the environmental product information it is necessary to define certain standards for making an average for these possible variations without neglecting relevant differences. Thus, e.g. tomatoes grown outdoors are investigated as a monthly average.

In order to overcome this problem, there need to be guidelines for the modelling of average supply chains. And there should be the possibility to include more detailed data in the modelling if the supply chain is well known.

4.3.8 LCI modelling approaches

Three main modelling principles may be distinguished, namely the attributional, the consequential and the decisional approach as shown in Table 4.4 and described in detail in sub-chapter 8.2 of the annexe. All approaches may be applied in a past or future situation. The attributional approach is used in reporting and the inventory model (the product system) is based on economical and/or contractual relations. The consequential approach is used for decision support (past and future) and the relations are identified with the help of computational general equilibrium models. The decisional approach is also used in decision support but the inventory model is based on future or planned economic and/or contractual relations.

Whereas both the attributional and decisional approach do not prescribe the allocation approach to be applied, the consequential approach is intimately linked to the avoided burden approach.

The environmental impacts related to the product or service under study differ too. The attributional and decisional approaches try to quantify the impacts caused by the product system supplying the average and extra consumption, respectively. The consequential approach tries to quantify induced impacts.

For the environmental product information, we recommend the attributional modelling approach.

Tab. 4.4 Main characteristics of attributional, consequential and decisional approach in life cycle inventory analysis

	attributional	consequential	decisional
purpose	reporting / decision support*	decision support	decision support
time	past or future	past or future	past or future
relations	physical, economical and/or contractual	identified via general equilibrium models	economical and/or contractual
environmental impacts	caused by product system supplying average consumption	induced by decision	caused by product system supplying extra consumption
multi-output processes and recycling	allocation or system expansion	avoided burden (system expansion)	allocation or system expansion
Main scientific contributions	Reinout Heijungs	Bo Weidema, Thomas Ekvall	Rolf Frischknecht

*: in today's practice, attributional LCA are still often used for decision support

4.3.9 Recommendations

Here we summarise the main recommendations concerning the LCI for elaborating an environmental information for products.

- Use the methodology applied in ecoinvent v2.0 for defining the allocation in case of multi-output processes.
- Only include direct emissions in the life cycle of the product, but do not account for indirect emissions.
- Do not allow inclusion of offsetting as part of the LCI.
- Model real product inputs according to economic relationships.
- Foreground and background system need to be defined in PCR.
- Use ecoinvent data as a background database. All other data need to be investigated according to the methodology of the ecoinvent project (Frischknecht et al. 2007b).
- Apply average data of the most recent year or in case of annual variations for the last five year period. PCR may define necessary deviations e.g. in case of vegetables which exhibit substantial variation in environmental impacts within one year.
- Use attributional modelling in the LCI.

4.4 Impact assessment

4.4.1 Introduction

The life cycle impact assessment (LCIA) phase of the LCA aims at evaluating the significance of potential environmental impact using the results of the LCI analysis. This procedure involves associating inventory data with specific environmental impacts and attempting to understand those impacts. The level of detail, choice of impacts evaluated and methodologies used depend on the goal and scope definition of the study (International Organization for Standardization (ISO) 2006a). The term impact assessment is used for all steps of aggregation.

It is necessary to choose appropriate impact assessment methodologies with regard to special emissions in the life cycle (e.g. agricultural chemicals), the region under study (e.g. Europe) and the decision-makers addressed. Often LCA studies use different impact assessment methodologies simultaneously in order to see and discuss differences in the outcome.

Every LCIA involves some subjectivity such as choice, modelling and evaluation of the impact categories. Therefore, transparency is critical to LCIA to ensure that assumptions are clearly described and reported.

4.4.2 Category indicators

Table 4.5 shows a short description of the most important LCIA category indicators. Different areas of protection are of concern. They have a recognisable value for society. Human health (HH) describes damage to human beings. Natural resources (NR) can be depleted and the opportunities of future generations may be constrained. The natural environment (NE) can be affected by human interventions, yet the man-made environment (ME) as well, e.g. buildings, can be damaged by human activities (Guinée et al. 2001).

Tab. 4.5 Short description of important category indicators in LCIA and areas of protection (partly from (Guinée et al. 2001)

Category indicator	Description	Area of protection
Depletion of abiotic resources	Abiotic resources (including energy resources) such as iron ore, crude oil, etc. which are regarded as non-living. There is a wide variety of methods available for characterising contributions to this category. Many studies focus on energy resources. The cumulative energy demand (CED) quantifies the entire energy demand, valued as primary energy. Different types of primary energy uses (i.e. fossil, nuclear, hydro, sun, wind, biomass) have to be described and characterised.	NR, HH, NE
Depletion of biotic resources	These are resources that are regarded as living, e.g. rainforests, fish stocks, animals, etc. Not many LCA studies account for these impacts.	NR, HH, NE, ME
Land use	This category covers a range of consequences of human land-use patterns. Different impact on e.g. the resource aspect, biodiversity or life support functions might be considered.	NR, ME
Water use	This category covers the use of water and impacts on the natural environment due to reduced availability. A regionalised impact assessment is necessary because of large variation of available water resources.	NR, NE
Climate change	This is defined as the impact of anthropogenic emissions on the radiative forcing of the atmosphere. This is also referred to as the “greenhouse effect” because in many parts of the world the emissions can cause a rise in ground-level temperatures.	HH, NE, ME
Stratospheric ozone depletion	This category refers to the thinning of the stratospheric ozone layer as a result of anthropogenic emissions. This causes a greater fraction of solar UV-B radiation to reach Earth’s surface, with potentially harmful impacts on living beings.	HH, NE, ME, NR
Human toxicity	Impact of toxic substances on human health are covered in this category. Some LCA also include workplace exposure in this category.	HH
Ecotoxicity	This category covers the impacts of toxic substances on aquatic, terrestrial and sediment ecosystems. Further subcategories are freshwater aquatic, marine, freshwater sediment and marine sediment ecotoxicity.	NE, NR
Photo oxidant formation	This describes the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants. These reactive educts may be injurious to human health and ecosystems.	HH, ME, NE, NR
Acidification	Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters and materials. The major pollutants are SO_2, NO_x and NHx.	NE, ME, HH, NR
Eutrophication	This covers all impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen and phosphorus. Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. Increased biomass production in aquatic ecosystems may lead to depressed oxygen levels.	NE, NR, ME
Waste heat	Waste heat may increase temperatures on a local scale.	NE, NR
Ionising radiation	This covers the impacts (e.g. cancer) arising from releases of radioactive substances.	HH, NE, NR
Noise	Impacts of noise from traffic or construction on human health.	HH

Areas of protection: HH – human health, NR – natural resources, NE – natural environment, ME – man-made environment

4.4.3 LCIA methods for environmental product information

The goal of the life cycle impact assessment (LCIA) is to show the impacts in an as simple and as accurate a manner as possible while still observing the state of the art in LCA methodology. An important requirement of International Organization for Standardization (ISO) is that weighting shall not be used for comparative assertions which are disclosed to the public. In such studies, a sufficiently comprehensive set of category indicators shall be employed.

It would be necessary to use mainly a one-score impact assessment method in order to easily compare different products with the environmental product information. Even if the shortcomings of such an approach are widely discussed and it does not conform to the ISO standard, it simply does not seem realistic to compare different impact categories for a wide range of products and to pass this information to consumers.

Due to the requirement concerning impact assessment, it will be difficult to elaborate an environmental product information in full accordance with the ISO standard on LCA.

Introduction

The selection of LCIA methods has been made by recognising only such approaches which provide an individual indicator (single-score), which are known in Switzerland and which cover a range of environmental impacts. The following LCIA methods are evaluated:

- Ecological scarcity method 2006 (Frischknecht et al. 2009b). The work was commissioned by the Swiss FOEN.
- Impact 2002+ (Margni et al. 2003, with own developments for toxicology effects and for other impact categories based in large parts on Eco-indicator 99 (H,A) (Goedkoop & Spriensma 2000). Work has been mainly done in the framework of Swiss university research.
- ReCiPe (Goedkoop et al. 2009), successor of Eco-indicator 99 (H,A) (Goedkoop & Spriensma 2000). The development was commissioned by the Dutch Ministry of Housing, Spatial Planning and Environment.
- Ecological footprint (Global Footprint Network 2009; Huijbregts et al. 2007; Wackernagel et al. 1996).

The following methods cover only one relevant environmental aspect. They thus do not fulfil the criteria of completeness and are considered only briefly:

- Carbon Footprint, CO_2-emissions, Global Warming Potentials, etc. (only climate change)
- Energy analysis, grey energy, cumulative energy demand, crude oil equivalents (only energy resources)
- Water footprint (only water resources)
- Ecological Rucksack, MIPS, etc. (only material consumption)

An extensive and up-to-date description of several LCIA methods has been elaborated by the EU (European Commission 2009b). Furthermore, a more detailed description of different methods has been produced e.g. by Frischknecht (2009). A second report describes the framework and requirements for Life Cycle Impact Assessment (LCIA) models and indicators (Hauschild et al. 2009). The report includes a detailed description of the areas of protection and impact categories. Assessments including a final weighting into one score are not part of this evaluation. Finally, the work should lead to recommendations for best practice in the EU.

Evaluation criteria

Table 4.6 shows a summary of the coverage of different environmental problems in the evaluated LCIA methods. The four methods on energy (CED), resources (MIPS), climate change (CF) and ecological footprint can cover only a very limited list of environmental problems. Thus, according to the criteria used in this feasibility study we recommend not to apply them for environmental product information as several other environmental problems cannot be evaluated.

The other methods cover a much larger range of environmental indicators. It is difficult to identify a clear difference between these methods according to the impact categories alone. The selection also depends on personal preferences as to which problems are considered more important than others. All existing LCIA methods have gaps concerning impact categories which are not yet integrated.

It has to be noted that the list of impact categories is not complete and may be revised in future if new environmental problems are better investigated. Some examples of impact categories not covered very well so far are salinisation, erosion, littering[20] or depletion of biotic resources as fish. Thus no LCIA method can really cover “all” environmental impacts.

There are also certain types of impacts which are not very well covered by thinking on life cycles of products. Examples are fires caused by accident or several illegal activities such as burning household waste as well as semi-natural emissions such as VOC from plants.

In order to make a better choice on the impact assessment method, further criteria according to Table 4.7 are applied. It is assumed that all LCIA methods in this table fulfil the criterion of being meaningful concerning the environmental impacts covered. All methods, with the exception of Impact 2002+, provide clear recommendations for the calculation of a single score as a result. None of the methods can really cover all environmental impacts, but all cover at least a range of important topics.

[20] For example, marine debris caused e.g. by shoreline activities, smoking related activities, fishing, discarded materials in sewers or dumping.

Tab. 4.6 Summary of different impact assessment methods and impact categories included

		One environmental issue			Aggregation of several environmental issues				
	LCIA method: Impact category	CED	MIPS	Carbon footprint	Ecological footprint	Ecological scarcity 2006	Impact 2002+	Eco-indicator 99	ReCiPe 2009
Resources	Energy, non-renewable	√	√ 2)	∅	∅10)	√	√	√ 6)	√
	Energy, renewable	∅	√ 2)	∅	∅	√	∅	∅	∅
	Ore and minerals	∅	√ 2)	∅	∅	√ 7)	√	√	√ 4)
	Water	∅	√ 2)	∅	∅	√	∅ 12)	∅	√ 1)
	Biotic resources	∅	√	∅	∅	∅	∅	∅	∅
	Land occupation	∅	∅	∅	√	√	√	√	√
	Land-transformation	∅	∅	∅	∅	∅	∅	√	√ 11)
Emissions	CO_2	∅	∅	√	√	√	√	√	√
	Climate change	∅	∅	√	∅	√	√	√	√
	Ozone depletion	∅	∅	∅	∅	√	√	√	√
	Human toxicity	∅	∅	∅	∅	√	√	√	√
	Particulate matter formation	∅	∅	∅	∅	√	√	√	√
	Photochemical ozone formation	∅	∅	∅	∅	√	∅	√	√
	Ecotoxicity	∅	∅	∅	∅	√	√	√	√
	Acidification	∅	∅	∅	∅	√	√	√	√ 3)
	Eutrophication	∅	∅	∅	∅	√	√	√	√
	Odours	∅	∅	∅	∅	∅	∅	∅	∅
	Noise	∅	∅	∅	∅	∅9)	∅	∅ 9)	∅
	Ionising radiation	∅	∅	∅	∅	√	√	√	√
	Endocrine disruptors	∅	∅	∅	∅	√	∅	∅	∅
Others	Accidents	∅	∅	∅	∅	∅	∅	∅	∅
	Wastes	∅	∅	∅	∅	√ 5)	∅	∅	∅
	Littering	∅	∅	∅	∅	∅	∅	∅	∅
	Salinisation	∅	∅	∅	∅	∅	∅	∅	∅
	Erosion	∅	∅	∅	∅	∅	∅	∅	∅

1) Only summation of all water uses
2) Quantified according to moved masses for extraction
3) Only terrestrial acidification
4) Including uranium as a mineral resource
5) Includes radioactive wastes and hazardous wastes stored underground
6) Not including uranium
7) Eco-factor for gravel
8) Part of assessment of working environment
9) Supplementing proposal made by Doka (2009) for traffic noise
10) Nuclear electricity was included in the original version (Wackernagel et al. 1996), but is not included anymore according to revised guidelines published in 2009 (Global Footprint Network 2009)
11) Only transformation of forests
12) Under development

Table 4.7 Further criteria for the investigation of impact assessment methods

LCIA method: Criteria	Ecological footprint	Ecological scarcity 2006	ReCiPe 2009	Eco-indicator 99	Impact 2002+
Suitable for all types of products	Yes. But all agricultural and forestry products will have a dominant impact due to direct land use.	Yes	Yes, but so far not much experience. Based on assumed weighting, nuclear power appears favourable.	Land use is dominant for agricultural products, but not well differentiated	Yes
Useful on regional and national level	Very useful because of comparison with overall capacity of planet Earth.	Yes	Yes	Yes	Yes
Regional focus and possible international transferability	Global focus	Weighting consensus for Switzerland. Political goals and actual emissions can be investigated for other countries or Europe as a whole. Regionalisation is facilitated. Former versions have been adapted e.g. to Japan.	Europe, weighting based on Swiss research work and scientific experts Regionalisation or extension to global situation difficult	Europe, weighting based on Swiss research work and scientific experts Regionalisation or extension to global situation difficult	Europe, no weighting proposed for aggregation. Regionalisation or extension to global situation difficult. Ongoing project to develop factors for North America
Final unit and understandable for communication	Square metre used for one year. Quite good because square metre is understandable and comparable with Earths' capacity.	Eco-points. One quadrillion points for one pollutant equals the annual emission according to the Swiss target value. This number has to be multiplied with the number of pollutants.	Points. One thousand points refer to average Emission of an European or World citizen.	Points. One thousand points refer to average Emission of an European citizen.	Points. One point of each of the four categories refers to the average pollution of an European citizen. If weighting adds to 100% one could also use this relation for the final result. At the moment there is no weighting proposal and thus the method cannot be used as a single-score indicator.
Separation of scientific modelling and social preferences	Oriented to communication.	Scientific characterisation of pollutants which contribute to problems (e.g. greenhouse gases). Weighting based on targets of Swiss legislation.	Scientific modelling of damages. Weighting based on preferences in an expert panel.	Scientific modelling of damages. Weighting based on preferences in an expert panel.	Scientific modelling of damages. No weighting proposed, which leads to the situation that points are just added up without weighting, which makes no sense from a scientific point of view.
Background data availability	LCIA factors for ecoinvent, but no transparent database of the community	ecoinvent, so far no data for regional water use and emissions of endocrine disruptors and diesel soot	ecoinvent	ecoinvent	ecoinvent

LCIA method: Criteria	Ecological footprint	Ecological scarcity 2006	ReCiPe 2009	Eco-indicator 99	Impact 2002+
Complexity of inventory analysis	Simple because concentration on only a few environmental problems.	Demanding. Focus on well monitored resources and emissions. Difficult for agricultural emissions of pesticides and heavy metals	Demanding because coverage of several emissions. In practice often only CO_2 and fossil energy are relevant. A specific issue is the importance of land transformation.	Demanding because coverage of several emissions.	Demanding because coverage of several hundreds of chemical emissions.
Outlook and future expectations	Will be further used on global scale mainly by NGOs	Plans to adapt the methodology and eco-factors to Japanese situation.	Assumed to be used more frequently as the successor of CML 2001. So far not much known about the reactions of the LCA public.	Obsolete. Replaced by ReCiPe 2009	Partly outdated. New focus on North America as main researchers changed working place. Mainly useful in the field of toxic impacts, but not as a one-score LCIA method

Recommendation

The ecological scarcity 2006 method should be used for environmental product information. The method is specifically designed to represent the assessment of environmental problems from the Swiss perspective. It covers many environmental problems and the method can be adapted to cover further environmental topics (e.g. more regionalised assessment of water use, noise, other environmental issues which are decided on the political agenda). The method is suitable for all types of products and can be used on a regional or national level.

Nevertheless also one of the other four methods on the right side of Table 4.7 might be used. ReCiPe is considered as the second best option, but so far there is not much experience with this method. The later case studies show that also the evaluation of nuclear energy might be seen as a shortcoming from a Swiss perspective. The weighting is not based on a formal European consensus finding, but only on preferences of selected scientists.

Impact 2002+ and Eco-indicator 99 (H,A) can be considered somewhat obsolete. Impact 2002+ also does not provide guidelines for the weighting and thus it is not useful for application to environmental information for products as long as there is no commonly agreed procedure for the weighting.

A shortcoming so far for each of the methods is the communication of the results. Therefore, further improvements are elaborated in section on the communication approach.

Outlook: Developing single-score LCIA methods in the international context

The ecological scarcity method reflects the political goals in Switzerland and thus is best suited to assist decision-making in this country. It weights environmental impacts – i.e. pollutant emissions and resource extractions – with “eco-factors”. The eco-factor is derived from environmental law or corresponding environmental targets. In its basic form, it can be structured in three elements: characterisation, normalisation and weighting. Normalisation is performed on the basis of the actual annual pollutant emissions or resource extractions for the whole of Switzerland (normalisation flow). Weighting is determined by the ratio of the current to critical flow. The current flow is the present flow of pollutant related to a given process or product. The critical flow is the flow of the same pollutant considered to be the maximum permissible level within the context of environmental policy goals.

Presently a similar approach is developed for Japan with the updated methodology of 2006. The former 1997 methodology has also been applied to other countries (such as Sweden, Norway, the Netherlands, and Japan). The updated method (2006) would also be suited to reflect the European legislation mainly of the EU and to develop a weighting set reflecting the continental political aims and emission situation. As far as global agreements are available one might also think of a global version, but it might be difficult to reflect the quite different perceptions on environmental problems, which are more relevant on a local or regional level.

The eco-factors of a pollutant differ from region to region because the current annual emissions used in normalisation vary from one region to the other and because usually the ratio of current to critical flow (the weighting factor) is different too. Thus, the eco-points of one product assessed with the Japanese version of ecological scarcity would be very different from the eco-points of the very same product assessed with the Swiss version.

Different weighting factors might be interpreted in a way that in countries with lower environmental standards, environmental impacts of the same product are assessed to be lower. This is because in this case the difference between current and critical flow would be smaller. On the other side, lower eco-factors might be calculated if the same environmental targets are already more close to being fulfilled in another country. This would be a reasonable justification for the same product having a lower score.

The weighting factors reflect national or regional policies and thus vary accordingly from one country to another. The normalisation flows should be the same when comparing products from different regions of the world from a Swiss or European perspective. A first step for international harmonisation would be to use European or global emissions for the normalisation. This would perfectly match with national or regional weighting factors and thus allow for a European or global but regionalised impact assessment. As a second step, it would still be necessary to investigate the political goals on the regional levels.

The ecological scarcity method does not completely rely on environmental mechanisms as prescribed by the ISO standard 14044. Hence, it could be difficult to gain broad global acceptance of the method within the LCA community. Some EU member countries could be interested in establishing national versions. After that, a joint effort of those member countries to implement a European version could perhaps be envisaged.

However, there is no need to establish a harmonised European version of the ecological scarcity 2006 based on EU targets. Furthermore, a nationally or regionally differentiating version using European normalisation values and country specific weighting factors is more appropriate. However, this would not allow using the same indicator results calculated in one country for a traded product sold in another country. Thus, it would be necessary to re-calculate the indicator results with the life cycle inventory already established for this product, if products are traded between countries. The workload would therefore be small if this can be done within the same life cycle inventory data and if the LCIA method valid for the specific regions is available in the calculation tool.

The ReCiPe method already looks at environmental problems from at least a European perspective. The basis for the evaluation of environmental impacts with regard to nuclear power does not consider the scarcity of underground nuclear waste repositories. That point aside, we see no need for further adaptations to use the method on a larger or more focused scale. For all other methods than ecological scarcity a consensus on cultural perspective and weighting is essential if it is to be applied for environmental product information in a specific regional area.

The possibility to develop a fully aggregating methodology for other countries does not mean that it would be accepted to the same degree in different cultures. One important issue is that a single-score weighting does not conform to ISO 14040 for the public comparison of product alternatives. This is why several stakeholders in other countries would refrain from using such a method. In addition, the perception on the feasibility of integrating social sciences in a technical approach is quite different.

4.5 Interpretation

Within the interpretation part, a final discussion of the LCI and the LCIA results is made. This should be done according to the defined goal and scope of the study in order to reach consistent conclusions and recommendations. The interpretation phase may involve the iterative process of reviewing and revising the scope of the LCA. It is checked whether the nature and quality of the data collected is consistent with the defined goal. The findings of sensitivity analyses should also be reflected in the interpretation.

A problem of environmental product information is that the interpretation of results is made mainly by the consumer based on very little information provided with the EPI. Thus, much knowledge gained during the investigation is not used for the interpretation by the consumer.

4.6 Critical review

A critical review facilitates the understanding and enhances the credibility of LCA studies. This is especially important if comparative assertions raise special concerns. The critical review is done by one or more external experts. The specification of the review process in the ISO documents is relatively general. Some basic requirements concerning the selection of the experts are listed (such as familiarity of the expert with the ISO 14040ff standards as well as his or her technical and scientific expertise) and concerning publication of the review report within the LCA report. The critical review process must ensure that:

- the methods used for the LCA are consistent with the international standard;
- the methods are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretation reflects the limitations identified and the goal of the study;
- the study report is transparent and consistent.

It is recommended that any environmental product information approach foresees such a critical external review with requirements similar to those laid out in the ISO standard.

5 Practical examples

In this chapter, we give some practical examples of products for which environmental information can be calculated with the method developed. The aim of the case studies is to analyse the relevant aspects to be considered for the development of EPI. This complements the evaluation in other chapters of this report. The case studies have an illustrative character and they shall not be used for the environmental product information or product comparisons of real products on the market.

5.1 Total environmental burden caused by Swiss consumption

5.1.1 Estimating threshold limits for environmental impacts caused by Swiss consumption

Within this section, we elaborate a proposal for the simplification of ecological scarcity results. First, we calculate the total environmental burdens per capita caused by Swiss consumption. In a second step, the necessary reduction factors for a sustainable development path are outlined which leads to goals for per capita eco-points. In sub-chapter 6.5 we make suggestions for easier communication of the ecological scarcity method based on these results.

The calculations within this chapter are updated in an ongoing study. They represent intermediate results in March 2010. Thus, readers interested in these results should look for the planned publication (Jungbluth et al. 2011) in order to see the latest and valid results.

An important question is whether and how the environmental impacts caused by Switzerland compare to the targets for a sustainable world or the political targets in Switzerland. A target for the environmental impacts caused per person in a sustainable world are so far not available. But we can estimate the level of environmental impacts that should be achieved according to the goals of Swiss politics and reflected in the method of the ecological scarcity. Such a threshold level is also important for the simplification of ecological scarcity results that could be used for environmental product information (see sub-chapter 6.5).

The starting point is the environmental impact of consumption in Switzerland. In total about 20 million eco-points are caused per capita in Switzerland in 2005. This result has been calculated with the total impacts of consumption divided by the Swiss population.

In Fig 5.1 the current and critical flow are introduced. The calculation of the current flow in Switzerland according to the ecological scarcity method includes domestic emissions and resource uses accounted for with the ecological scarcity method (Frischknecht et al. 2009b). Part of e.g. the energy resource extraction takes place outside Switzerland.

The critical flow defines the target according to Swiss politics for domestic emissions and resource uses of Switzerland (including energy resources extracted abroad). The difference between the two columns ‘current flow’ and ‘critical flow’ defines the total reduction target for direct emissions and resource uses in Switzerland of about 40%. Thus the current flow amounts to about 7 million eco-points per capita. But reduction targets for single emissions and resource uses are not unique. Thus, e.g. reduction targets for air emissions are set higher while for natural resources there is only a small reduction target (Frischknecht et al. 2009b).

The goal is to define a critical burden of total environmental impacts (a kind of environmental budget) that can be caused per Swiss capita. This includes the emissions and resource uses attributable to trade in goods and services. Such a target figure is necessary if one wants to relate the environmental impacts of a specific product or activity to a threshold level of sustainable consumption.

For calculating the critical burden the same reduction targets as found for the critical flow have been applied to the seven categories of emissions and resource uses. Assuming that the total environmental burden caused by Swiss consumption and production should not exceed the total environmental impact per capita acceptable in Switzerland, the reduction target is about the same as for the direct impacts. This results in about 12 million eco-points as the target environmental impact to be caused per capita and year.

In an even stricter point of view one could also argue that Switzerland should aim at a neutral trade balance for environmental impacts. Or in other words we should (in balance) not burden foreign people with environmental impacts caused by our consumption. With this point of view total environmental impacts would be limited to the critical flow defined by Swiss politics. A reduction by more than 60% would be necessary.

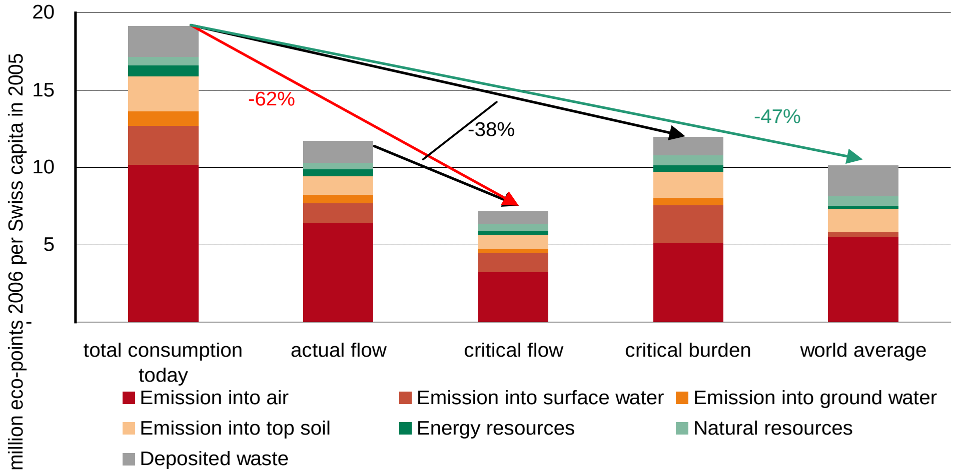
In a global perspective, one could also argue that environmental impacts caused by Swiss consumption should not be higher than the world average. Such an average has been roughly assessed with normalisation data provided by the ReCiPe methodology (Goedkoop et al. 2009). As this methodology does not account for waste deposits, these had to be estimated roughly with Swiss data. With this, a reduction of 47% of total environmental impacts should be aimed at in order to not further increase environmental impacts in a global perspective. This would not yet decrease the environmental burden today but would ensure equal opportunities for all people.

A considerable reduction of emissions and resource uses is necessary in the light of reasonable choices for setting a sustainability target. These examples reveal a need for further discussion on how to define more exact targets for sustainable consumption and production. The present analysis can provide the necessary background data for such a discussion. For our part, we would propose to aim at least for a 40% reduction of the environmental impacts caused by present Swiss consumption.

The reduction targets are calculated using the environmental impacts of the year 2005 according to the ecological scarcity method for each environmental compartment (e.g. emissions to water or air). The reduction factors are then applied to the environmental impacts of consumption. According to this the critical burden would be at least 38% less compared to the present environmental impact caused by Swiss consumption. Two other approaches considering no net imports or world average would result in reduction targets of 62% and 47%, respectively.

A critical point is the time frame of achieving the critical burden. We see a time frame of about 20 years within which the critical burden should be achieved. This is in the range covered by political decisions which build the underlying framework for the development of this LCIA method. Thus, one might develop an annual reduction target within providing environmental information for products. A linear calculation would set the target each year 400’000 eco-points lower. Thus in 2010 it is 19.6 MM eco-points, in 2011 it is 19.2 MM eco-points and so on.

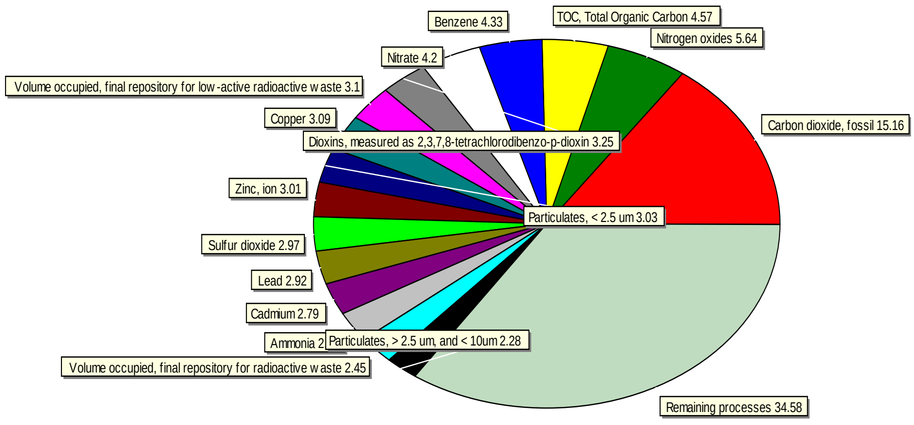
Fig. 5.1 Estimation for the target value or critical burden of total environmental impacts caused by Swiss consumption. Preliminary results to be revised in an ongoing project (Jungbluth et al. 2010c)



5.1.2 Analysis with different LCIA methods

Fig 5.2 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the ecological scarcity LCIA method. Carbon dioxide is the most important emission. This is followed by other air and water pollutants.

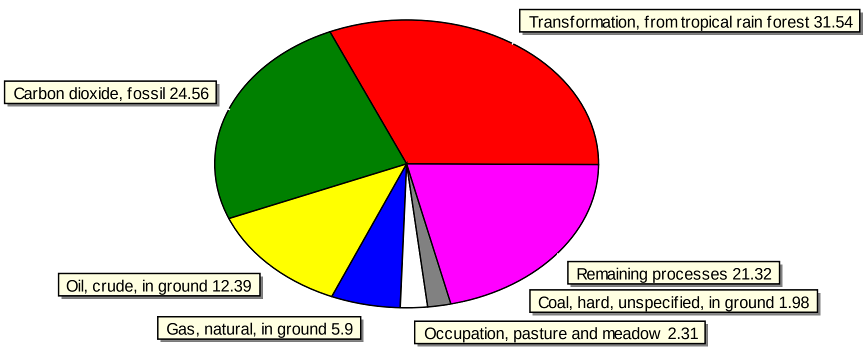
Fig. 5.2 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, ecological scarcity method 2006. Preliminary results (Jungbluth et al. 2010c)



ng 1 p 'Total emissions, per capita/CH U'; Method: Ecological Scarcity 2006 V1.02 / Ecological scarcity 2006 / single score

Fig 5.3 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the ReCiPe LCIA method. The most important aspect is the import of tropical fruits (coffee, cocoa, palm oil) used in different products. These products lead to a land-transformation due to clear cutting of tropical rain forests. With the inventory flow concerning transformation of forests, the loss of biodiversity is assessed in this LCIA method. In contrast, the loss of biodiversity due to land-transformation is not assessed within the evaluation with ecological scarcity 2006. Carbon dioxide and energy resources are also important.

Fig. 5.3 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, ReCiPe, endpoint (H,A). Preliminary results (Jungbluth et al. 2010c)



Analysing 1 p 'Total emissions, per capita/CH U'; Method: Recipe Endpoint (H) V1.01 / Europe Recipe H/A / single score

ws an evaluation of the most important pollutants while assessing the total impacts of Swiss n with the Eco-indicator 99 (H,A) LCIA method. The method considers land-transformation ...ite important. However, it has to be considered partly as an artefact as transformation from and to of all types of land uses are both inventoried separately in the same dataset. Hence, the net impact from land transformation is the sum of all transformation to a type of land use plus the sum of all transformation from a type of land use (with a negative sign). ReCiPe, in contrast, only considers transformation of forest land. Most important are energy resources and land occupation. Carbon dioxide emissions are less important than in other LCIA methods evaluated before. This may reflect the fact that the issue of global warming has attracted more attention in the recent past and thus weighting in e.g. ReCiPe or ecological scarcity has been adapted.

Fig. 5.4 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, Eco-indicator 99, endpoint (H,A). Preliminary results (Jungbluth et al. 2010c)

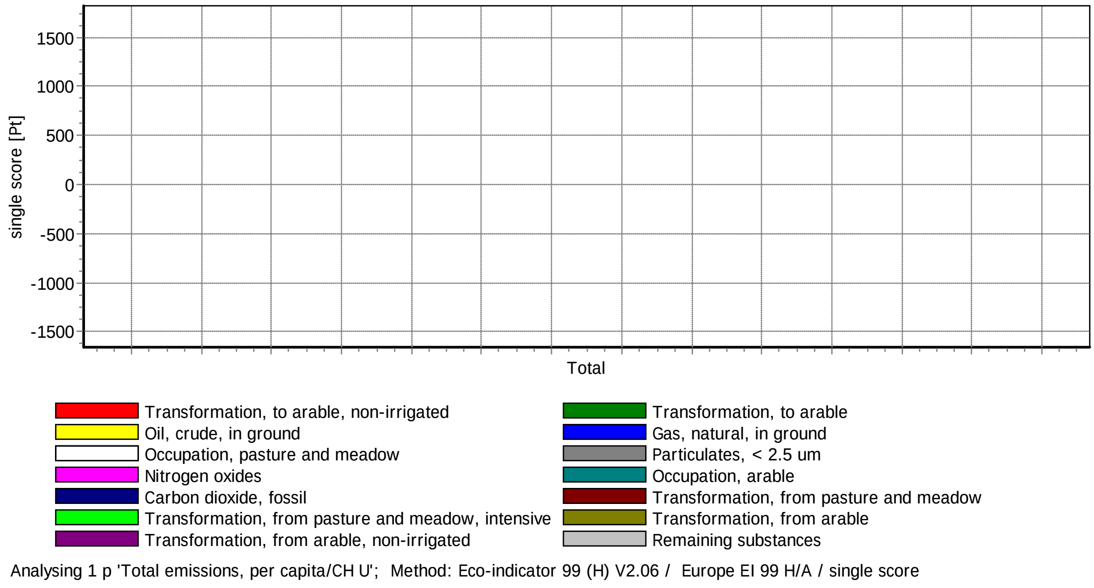


Fig 5.5 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the Impact 2002+ LCIA method and an equal weighting of the four damage categories. Carbon dioxide and energy resources are also important. An important aspect is the emission of zinc to soil in Switzerland that accounts for 11% of the total impacts.

Fig. 5.5 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, Impact 2002+, equal weighting of four damage categories. Preliminary results (Jungbluth et al. 2010c)

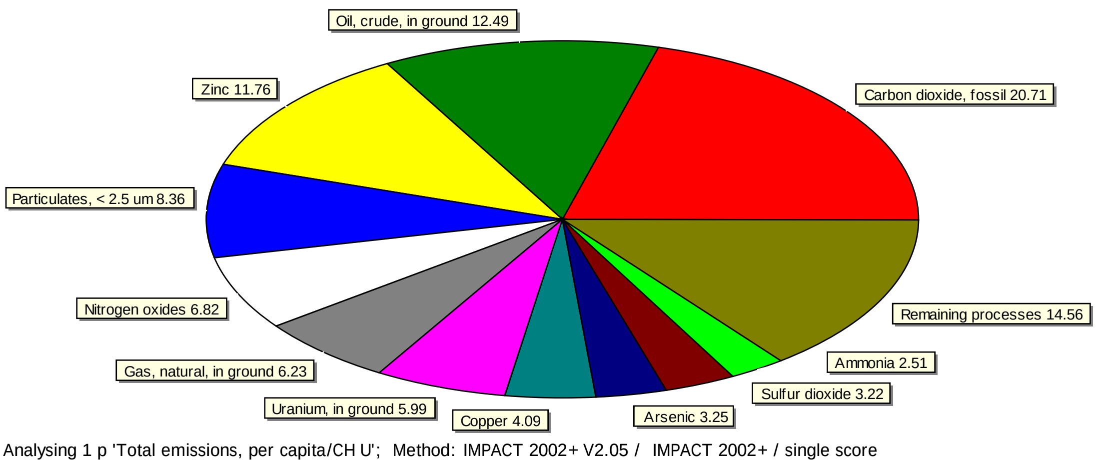
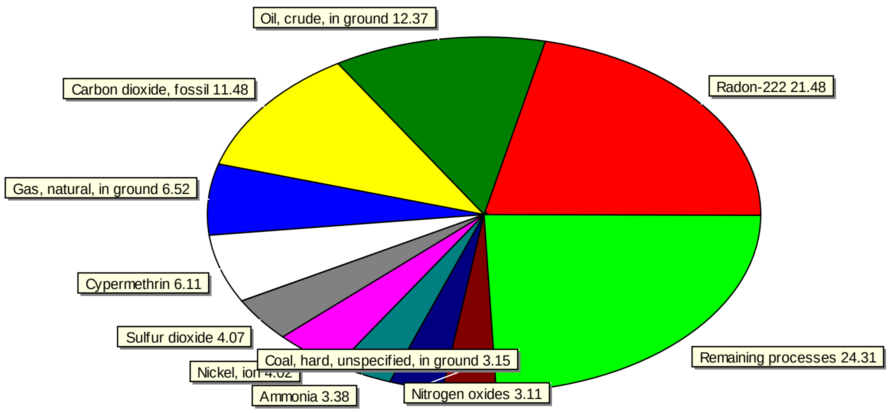


Fig 5.6 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the EMC (Environmentally weighted Material Consumption) method. We made the necessary implementation within the SimaPro software based on information provided (van der Voet et al. 2005). We used the normalisation factors provided for the world in 1995 and an equal weighting set. The 'final solid waste" had to be omitted because inventory data were not available.

The most important impact according to this methodology is long-term radon emissions. Its share (20%) is higher than the weight of 10% given to the full category of radioactive emissions. Because such long-term emissions are not accounted for in the normalisation the annual emissions can be higher than assumed for the normalisation. Other important aspects are fossil resources, CO_2 and SO_x emissions.

Fig. 5.6 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, environmentally weighted material consumption. Preliminary results (Jungbluth et al. 2010c)

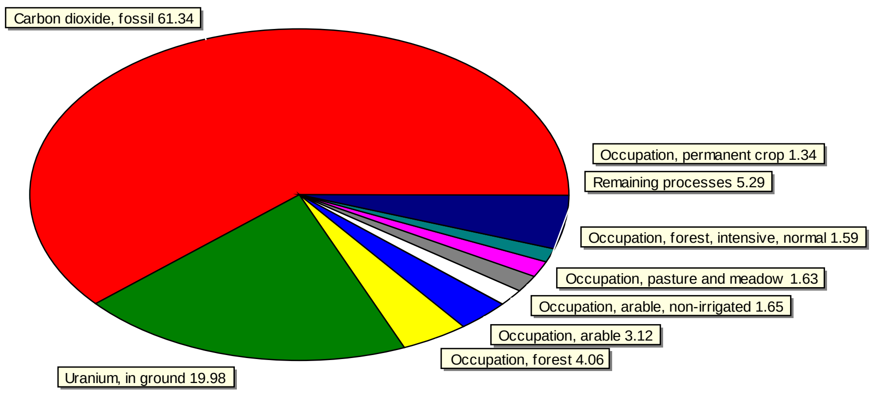


Analysing 1 p 'Total emissions, per capita/CH U'; Method: CML 2001 (all impact categories) V2.04 / EMC, world 1995, equal / single score

Fig 5.7 shows an evaluation of the most important pollutants while assessing the total impacts of Swiss consumption with the ecological footprint LCIA method (Huijbregts et al. 2007). Two third of the environmental impacts is due to CO_2 emissions. About 13% is due to uranium used in nuclear power plants and the rest are direct land uses by different processes mainly in agriculture and forestry. The total ecological footprint amounts to about 4.7 hectare per person in Switzerland. This total is similar to the figure calculated with a quite different approach (von Stokar et al. 2006).

It has to be noted that the newest version of the ecological footprint standard excludes uranium from the assessment (Global Footprint Network 2009).

Fig. 5.7 Shares of individual emissions and resources in the total environmental burden caused in Switzerland, ecological footprint. Preliminary results (Jungbluth et al. 2010c)



Analysing 1 p 'Total emissions, per capita/CH U'; Method: Ecological footprint V1.00 / Ecological footprint / single score

5.1.3 **Conclusions**

For understanding the differences between LCIA methods, an assessment with each LCIA method of the overall annual environmental impacts of Switzerland is helpful. All methods see global warming, energy depletion and land occupation as important issues. In some methods these categories fully dominates the results while the ecological scarcity methods shows a more balanced picture of several environmental impacts. These differences do not allow conclusions about one method being superior to another. Therefore, the point of view of the decision-maker has to be taken into account.

5.2 Suggestions for case studies

Several products from a wide range of categories are considered for case studies. The following Table 5.1 suggests examples.

For the evaluation of the life cycle, we distinguish five different stages with different levels of influence by the actors in the life cycle. This further develops the approach proposed by Känzig *et al.* (2006), who only distinguish between 'passive' and 'active' products (the latter having an important use phase). Furthermore they distinguish between 'mobile' and 'static' products with 'mobile' products having important environmental impacts during transportation or movement (Känzig & Jolliet 2006:23). This relates to the delivery and use phase in our structure. In our view, it is important that the importance of the use phase of a product is not restricted to energy consumption, but can also come from other means of combustion or from products entering into effluents (washing powder, pharmaceuticals, etc.) or soil (plant protection agents). Thus, also a passive product such as medicines can have an important use phase.

The definition of mobile is also not straightforward as one has to know whether the transportation is important for environmental impacts before assigning a product to the "mobile" category. Thus, the categorisation does not help for deciding about the importance of certain products, but this has to be known before.

Depending on who is responsible for the environmental product information, parts of the process stages are downstream while others are upstream. Downstream processes will be more difficult to quantify than upstream processes.

The suggestions for the case study have been discussed with the steering committee. The following products were chosen for an in-depth evaluation:
- Vegetables (spinach, carrots)
- Textiles
- Electricity
- Mineral water
- Cars

Tab. 5.1 Proposed examples to be evaluated in a case study and first guess on the importance of the four main stages in the life cycle

Product	Production and packaging	Distribution	Delivery	Use phase	End of life treatment	Source
		Upstream	- · - · - · - · - · - · - · - · -	- · - · - · - · - · - · - · - · -	- · ►	
	◄ - · - · - · - · - · - · - · -	- · - · - · - · - · - · - · - · -		Downstream		
Mineral water	Only low importance of production, but packaging is important	Important, might vary considerably depending on point of sale	Impacts depend on size of bottles and boxes. Large units can only be transported by car.	No influence of the product. Consumer can decide between chilled and unchilled.	Littering might be a problem, differences between recycling and combustion	(Jungbluth & Faist Emmenegger 2005)
Orange juice	Important, regional differences	Different transport chains to CH e.g. frozen or concentrated	Important if transported by car	Cooling might be necessary depending on product type.	Recycling of packages	(Classen & Jungbluth 2002)
Vegetables	Important, large regional and seasonal variation.	In some cases important, e.g. air freight	Several options e.g. local shop or market. Supermarket only reachable by car. Home delivery.	No influence of the product. Consumer can decide about preparation e.g. cooking.	Losses are important.	(Jungbluth 2000)
Ready made Lasagne	Important, e.g. recipes, agriculture, conservation	Conservation (chilled or deep-frozen) influences	Same as vegetables	Cooling and heating are dependent on the product and consumer behaviour	Not relevant, but best options should be shown	(Büsser & Jungbluth 2009a; b)
Renewable electricity according to *naturemade star*	Important, plant specific differences	Relevant in case of losses, controlled by the grid operator.	Included in distribution.	Indirect influence of the product because use might be considered as less harmful.	None	(Frischknecht & Jungbluth 2000; Jungbluth et al. 2010b)
Fuels	Important especially for biofuels, no packaging	Not relevant	New fuels might be available at fewer filling stations and thus induce extra driving.	Combustion emissions must be considered for a comparison of fuels	None	(Jungbluth et al. 2008; Zah et al. 2007)
Cars	Some importance. Considerable workload for investigation.	Minor relevance.	Minor relevance	Direct emissions and fuel consumption are important. Consumer behaviour has large influence.	Recommendations necessary	(Spielmann et al. 2007)
Washing powder	Important	Some relevance of packaging.	Minor relevance	Inclusion of energy use and washing machine necessary if comparing products for different temperatures.	Emissions to waste water are important.	

Product	Production and packaging	Distribution	Delivery	Use phase	End of life treatment	Source
		Upstream	◄- · - · - · - · - · - · - · -			
			- · - · - · - · - · - · - · - · - · - · ►	Downstream		
White goods	Important	Not relevant	Home delivery or transported by private car.	Influenced by technology and consumer behaviour	Recommendations necessary	(Faist Emmenegger & Frischknecht 2004; Jungbluth 1997; Steiner et al. 2005)
Textiles	Important	Relevant due to distribution shops, air transports or marketing..	Not relevant	Influence of washing is important. Thus, type and washing temperatures have an influence.	Many textiles or are given to charity organisations. Implications are not clear.	(Classen & Jungbluth 2002)
Tennis course	Facilities as e.g. tennis hall might be important.	Not relevant.	Relevant if transport to tennis facilities is necessary.	Impacts due to use of clothing and equipment bought by the consumer.	Not relevant.	
Cell phones	Important	Not relevant	Not relevant.	Influenced by technology and consumer behaviour, usage time also important	Recommendations necessary	(Faist Emmenegger et al. 2003)
Coffee machine	Important	Not relevant	Not relevant	Important if different types of coffee can be used by different products. Energy use is also a factor	Recommendations necessary.	(Büsser et al. 2008)

5.3 Questions partly answered by the case studies

Several aspects should be considered for the development of environmental product information. The case studies should help to answer the following questions in the development of an approach:

- What is a good approach to define the functional unit?
- Which product category rules should be considered?
- Which actor in the life cycle oversees best the environmental impacts caused by product and thus should be involved in information and communication?
- How can the different stages of the life cycle be considered in the environmental product information?
- What are the demands on data collection? Which data can be used for background systems? Where are data for a foreground system necessary and can they be provided by producers and retailers?
- With which accuracy can the environmental impacts be distinguished between more or less similar products?
- What differences occur while using different LCIA methods?

5.4 Case study on vegetables (spinach and carrots)

The case study on spinach is based on a detailed LCA study (Büsser et al. 2008). Life cycle inventory data are also based on former studies of vegetables (Jungbluth 2000; Jungbluth et al. 2010a).

5.4.1 System boundaries

The life cycle of spinach encompasses the whole food supply system from the cultivation of spinach to the preparation of frozen spinach in the kitchen ready to eat. The process steps for deep frozen spinach production are: cultivation, harvesting, transport by lorry, sorting, dry purification, washing, blanching, and quick-freezing. Spinach is frozen within two or three hours after harvest and has then to be stored and transported at a temperature of at least minus 18°C. The cold chain consists of three different cold stores (at the processing plant, in a storage warehouse, at the regional distribution centres), the supermarket and refrigerated transports. At home, spinach can be stored in freezers up to almost two years.

Packaging of frozen spinach is quite simple compared to the packaging of highly processed products. The analysed packaging consists of a typically used linear low-density polyethylene (LLDPE) bag.

The functional unit concerning deep frozen spinach is ‘the preparation of one kilogram of spinach ready to eat at home’.

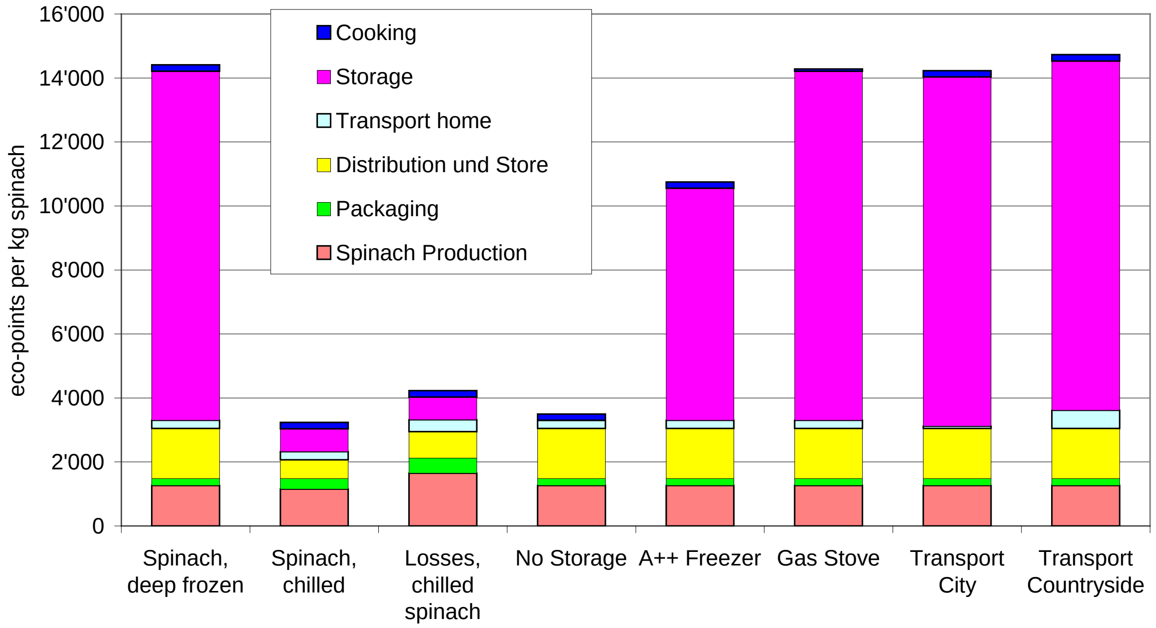
The impact assessment of deep frozen spinach consumption includes a standard case with the following assumptions: an average production of deep frozen spinach, LLDPE packaging, refrigerated storage and transportation at minus 18°C, domestic storage for 180 days in a B-class freezer, cooking spinach for ten minutes with an electric stove and the European electricity mix.

5.4.2 Analysis of scenarios

The study shows: the most relevant aspects regarding the life cycle of deep frozen spinach are the refrigeration (storage at home and during distribution and selling) and the spinach production – compared to retail packaging, transport (from the supermarket to the household) and cooking which are of minor importance. Keeping spinach deep-frozen is, due to the long storage time, the most energy consuming process and responsible for most environmental impacts in all indicators except for eutrophication.

The sensitivity analysis compares modified parameters – e.g. chilled spinach with/without 30 percent spoilage, A++ and C class freezer, gas cooking, packaging disposal in a landfill site instead of incineration – to the standard scenario.

Fig. 5.8 Sensitivity analysis with regard to ecological scarcity 2006



The sensitivity analysis shows the following results: Chilled spinach (if no spoilage assumed) has lower impacts than deep frozen spinach for all indicators considered mainly because of the shorter storage time. The domestic storage time is the most sensitive parameter in all indicators. When frozen spinach is consumed directly after buying, the impact in cumulative energy demand decreases about 61 percent compared to the case where spinach is kept for 180 days. The use of an A++ class freezer leads to savings in energy demand and global warming potential of about 30 percent. The use of a gas stove instead of an electric one has positive effects except for ozone layer depletion due to emissions at gas gathering. The disposal of packaging has practically no influence on the results because of the low share of packaging in the total environmental impacts. Means of transport and shopping distances are of limited importance.

The best case consists of no domestic storage, usage of a gas stove, packaging is disposed in incineration and for grocery shopping, the urban scenario is taken. The worst case applies to 180 days of storage in a C-class freezer, usage of an electric stove, landfilled packaging and countryside grocery shopping.

Conclusions for the consumption of spinach: The most relevant factors concerning the environmental impact from the whole supply chain are, for most indicators, storage of deep frozen spinach at home, refrigerated storage and transportation in the cold chain, and spinach production in agriculture. Therefore, the most relevant measures reducing environmental impacts are improving agricultural practice, to minimise the storing time of deep frozen spinach at the household and the use of efficient electrical household appliances.

With the application of hydrocarbons and CO_2 as refrigerant in distribution and selling points, the environmental impacts concerning ozone layer depletion can be decreased in future. Even if the cold chain improves, the storage of deep frozen spinach remains an issue.

With regard to the impacts of packaging in the life cycle of deep frozen spinach it is to say that they are small and not of primary importance. However, in case of chilled spinach the share of packaging to the environmental burdens are more significant in some indicators. The chilled spinach has a much lower density. Thus, a higher specific amount of packaging compared to the product packed is necessary. Furthermore, there is a lower impact from other processes (shorter storage time, no blanching, no freezing), which also leads to a higher share of packaging in the life cycle of chilled spinach.

5.4.3 Comparison with different LCIA methods

Fig 5.9, Fig 5.10 and Fig 5.11 show the ten most important emissions and resource uses in the LCIA with different methods. In all methods, carbon dioxide is an important factor. However, for other emissions and pollutants there are some differences concerning their weight in the total results.

Even with these significant differences in details, overall conclusions concerning the importance of different variations in the life cycle are similar.

Fig. 5.9 important emissions and resource uses with regard to ecological scarcity 2006

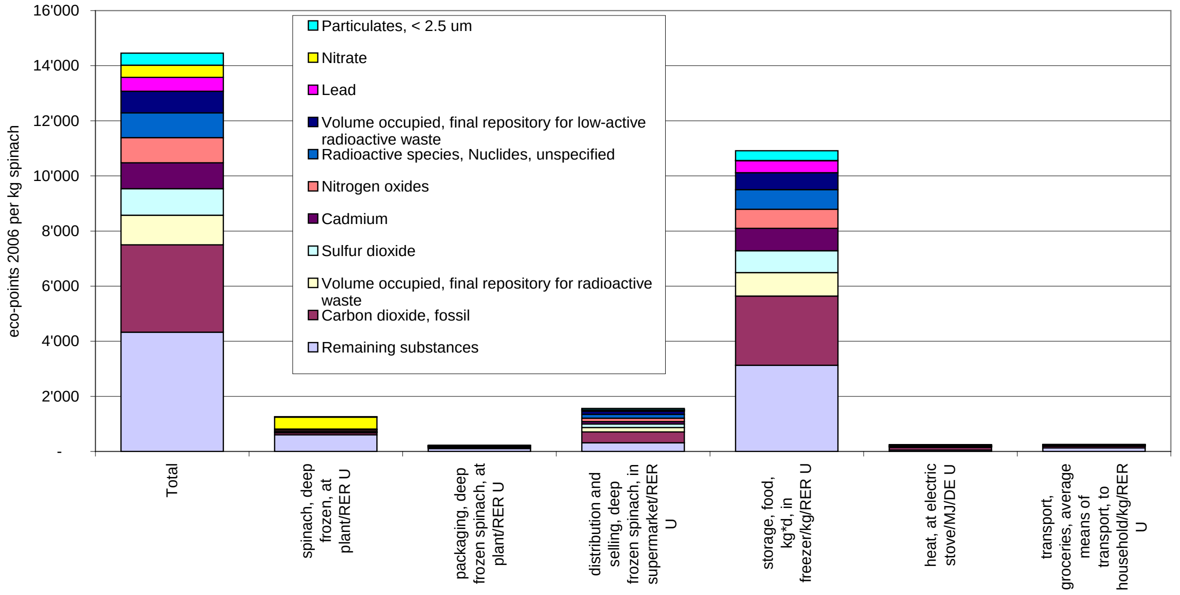


Fig. 5.10 Most important emissions and resource uses with regard to ReCiPe (H,A)

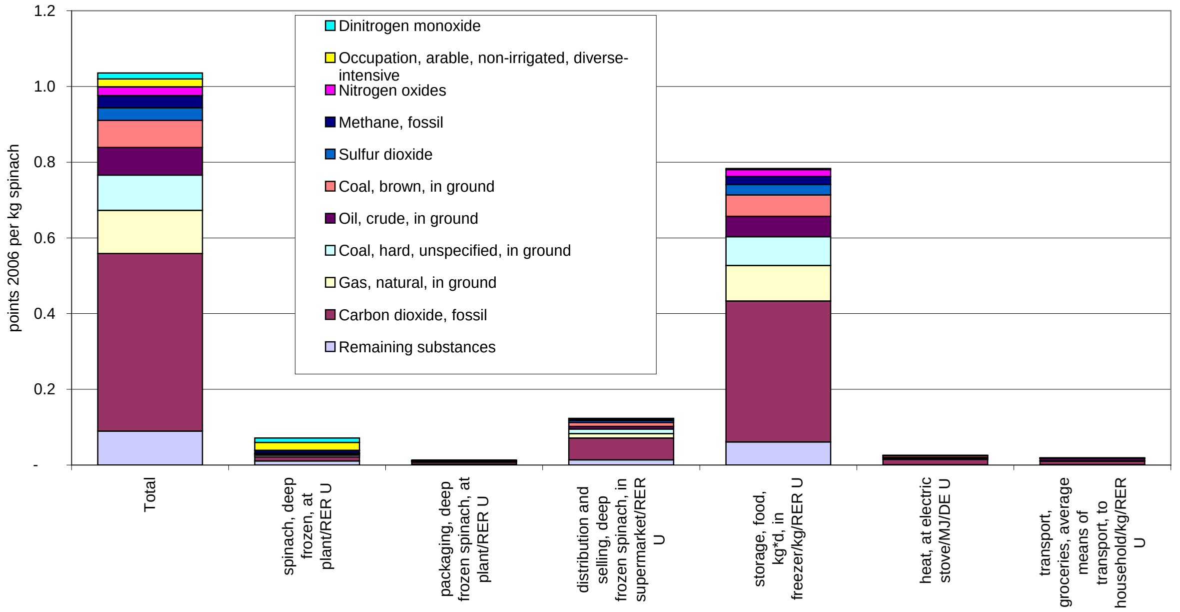
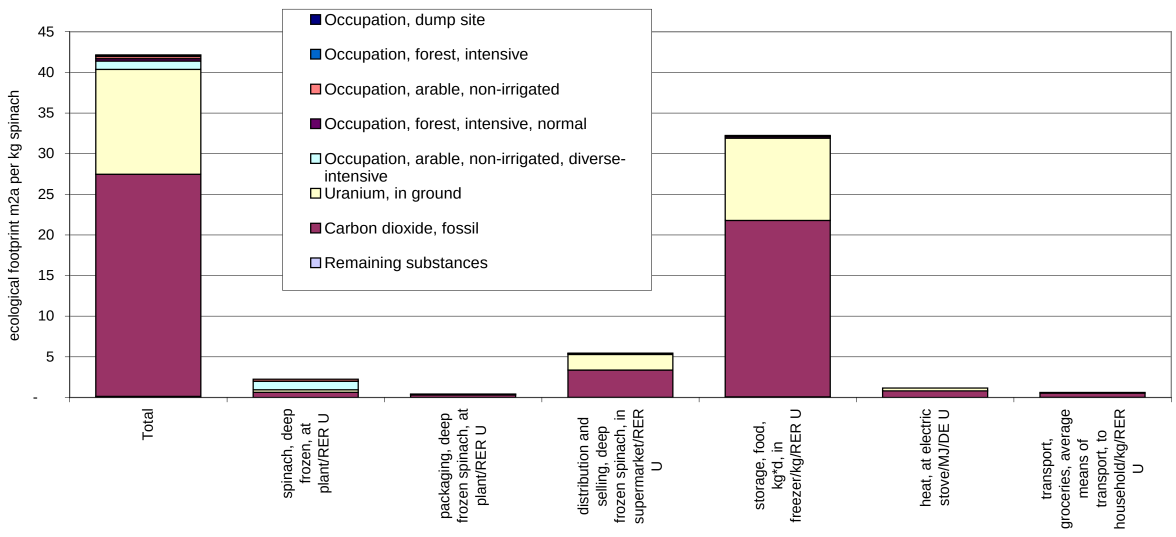


Fig. 5.11 Most important emissions and resource uses with regard to the ecological footprint



5.4.4 Variation of agricultural data and implications for the LCIA

An important aspect for agricultural products is the variation of data between different farms, years, regions, production patterns, etc. Also the models for estimating emissions are undergoing development and can change over time. To illustrate this we make here a specific evaluation with carrots produced in four different types of production patterns (two for integrated production and two for organic production). Carrots (instead of spinach) were chosen as an example where we had a range of different data available.

The life cycle inventory data have been revised three times. The first data are based on the emission models developed in a Ph.D. thesis (Jungbluth 2000) and statistical production data of 1999 (VSGP et al. 1999). This approach is named “2000”. The way in which some agricultural emissions (mainly N and P emissions) have been modelled has been revised later based on the approach used in ecoinvent (Nemecek et al. 2007) and is named here “2007”. This year we have updated again the underlying production statistic data with data for 2009 (VSGP et al. 2009). For each year we also considered variations of the production e.g. of carrots for storage or processing as well as “Paris carrots”.

This influences basic data on yield, fertiliser use, but also the assumptions concerning the amount and type of pesticide used. All LCI data are linked to ecoinvent v2.0 as background data.

The evaluation with different LCIA methods in Fig 5.12 to Fig 5.15 reveals some quite important differences in the LCIA methods and highlights the influence of data variations and methodological developments. All results are shown per kilogram of carrots harvested by the farmer. No downstream impacts are taken into account.

The assessment with the ecological scarcity method in Fig 5.12 shows that an important part of impacts is due to the use of pesticides and copper for plant protection. Due to variation in the type of pesticides and the amount used, quite important differences over the years and over the type of production pattern could be observed. Conclusions based on such an assessment are thus variable. In reality, it will be difficult to investigate good and reliable data on pesticide use as this varies from farm to farm and year to year. Also the type of pesticides used, does influence the results considerably in an LCIA with this method. It is quite time consuming to get reliable and detailed inventory data for the pesticide use while growing vegetables.

It is possible that the ecological scarcity method overestimates the importance of certain pesticide types as the application rates according to the new data are higher than the figures taken into account during the development of the method. During the development of the LCIA method, an average of different applications doses has been taken into account. Sometimes one pesticide is applied more than once on a crop, which has not been considered. Another issue is the determination of the eco-factor for copper that is derived differently compared to other types of pesticides. Thus, there are some uncertainties and choices in the modelling of the eco-factors that have important implications for the results calculated with this method. Therefore it might be necessary to revise the method after a detailed check of the results for several agricultural products.

Differences between organic and integrated production get less pronounced if a use of copper in organic agriculture is inventoried (which was not the case according to the data sources used in the first two assessments). Copper causes quite important impacts according to the ecological scarcity method that outweigh all other effects in agricultural production.

Thus, an impact assessment with the ecological scarcity method for vegetables has a high uncertainty and variation as well on the LCI side as on the LCIA side. The workload for elaborating information would be higher than the workload for an evaluation with an LCIA method that is less sensitive to the issue of pesticides and copper.

Fig. 5.12 Main pollutants in the LCIA of carrots with the ecological scarcity 2006 method (eco-points per kilogram)

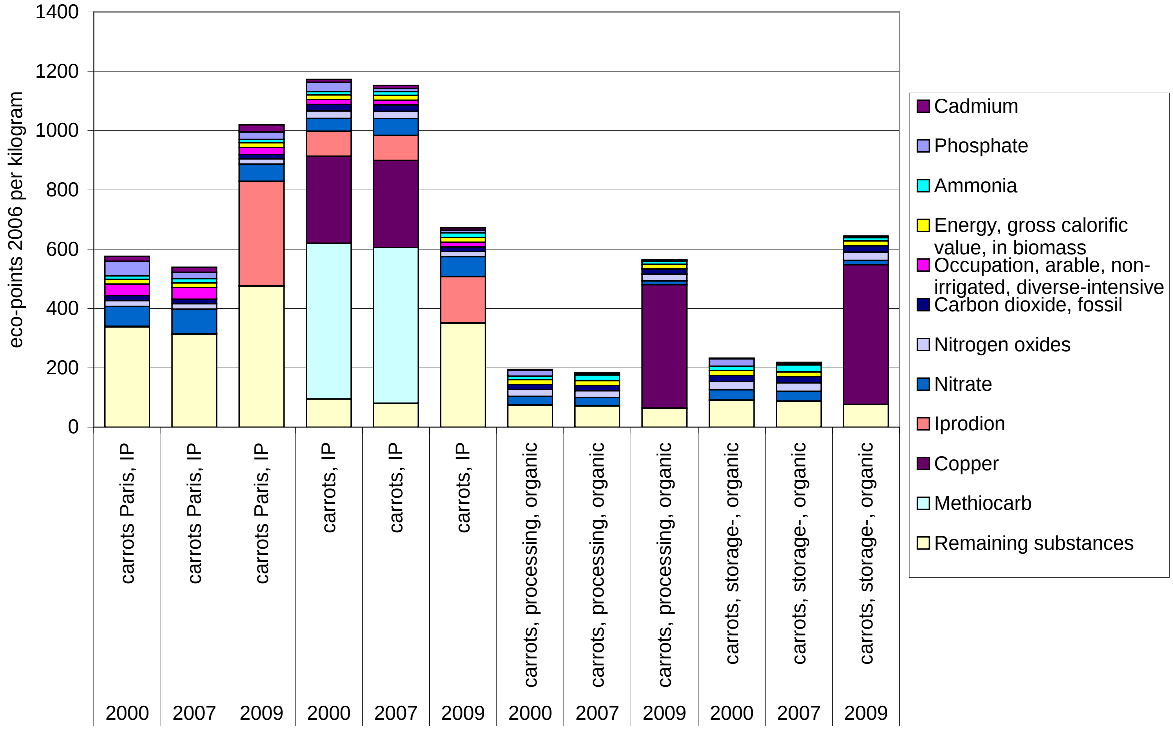
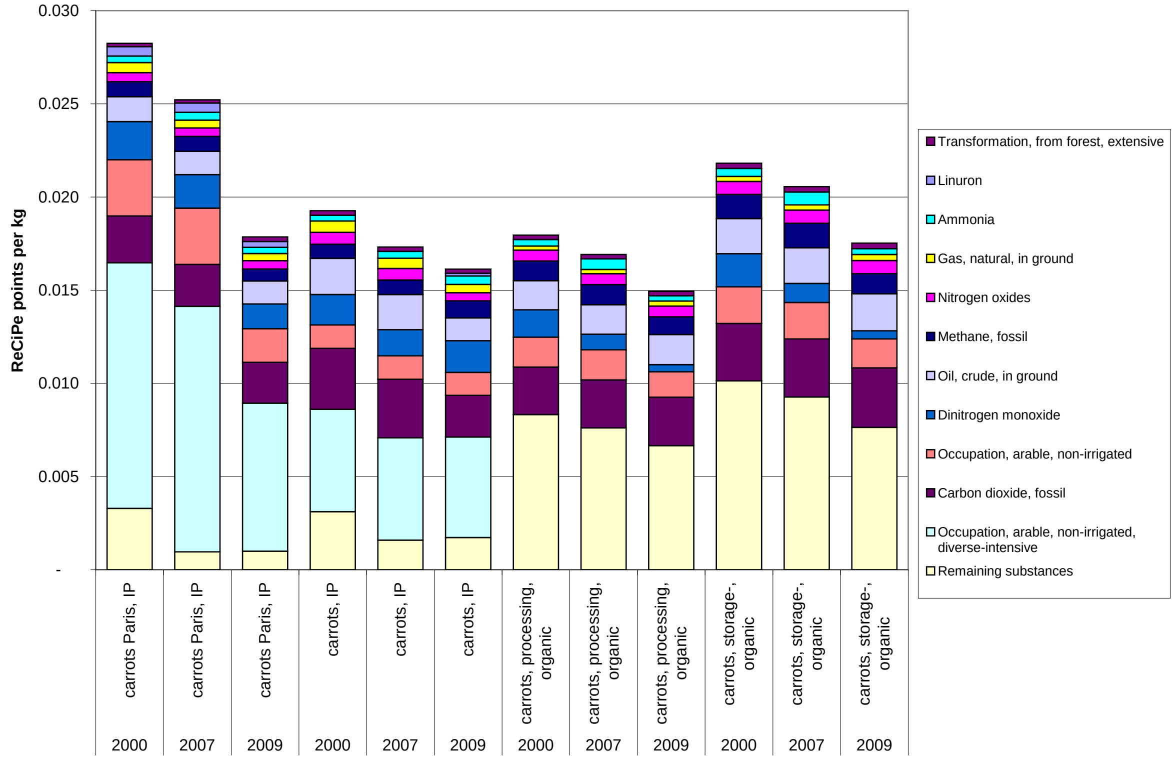


Fig 5.13 shows the evaluation with the ReCiPe method. The results are more stable over the years and the different crops compared to the results assessed with the ecological scarcity method. This reflects the fact that the main influencing factors for an impact assessment with the ReCiPe method, which are fertiliser and machinery use as well as yield, do not show such a high variation as the pesticide use. The main differences in Fig 5.13 are due to the changes in yield between 2000 and 2009 and thus different land occupation results. Differences between organic and integrated production are less pronounced as pesticides do not play an important role in the assessment.

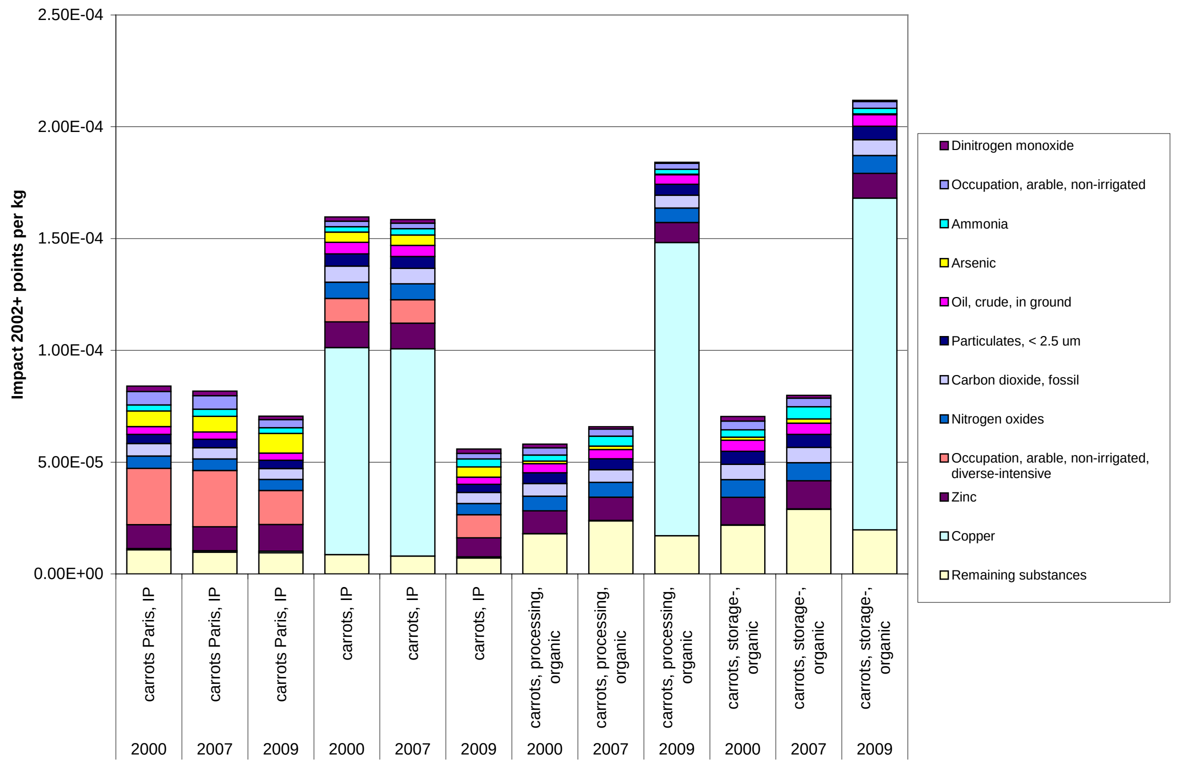
Fig. 5.13 Main pollutants in the LCIA of carrots with the ReCiPe method



The following Fig 5.14 shows an assessment with Impact 2002+ and equal weighting of four damage categories. The most important aspect in the variation is the use of copper as a plant protection agent. Cropping systems using copper show much higher impacts than those using other types of pesticides. Due to this condition, organic products exhibit sometimes higher impacts than these from integrated production. Another important factor is the land occupation and thus the yield achieved.

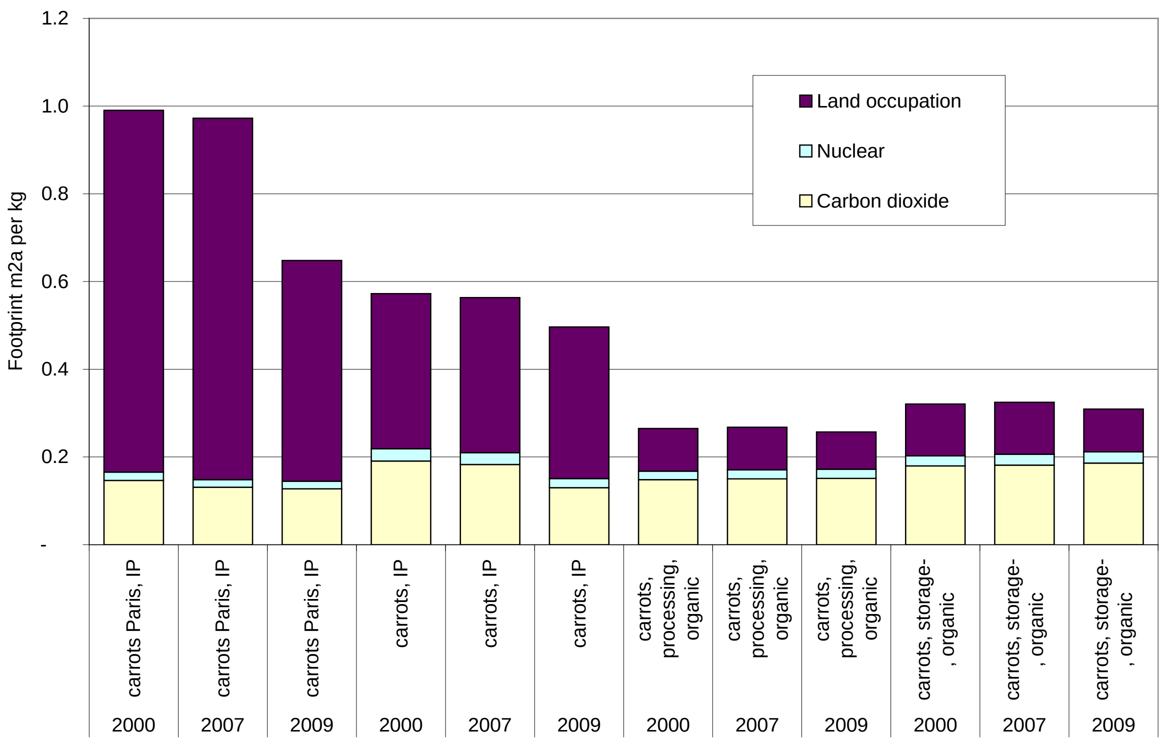
In conclusion, with the Impact 2002+ method there are quite high variations in the indicator results of vegetables depending on how much copper has been inventoried. This amount of copper might vary considerably between different farms, crops and years.

Fig. 5.14 Main pollutants in the LCIA of carrots with the Impact 2002+ method



As a last example in this chapter, Fig 5.15 shows the ecological footprint of the different types of production patterns. There are not many differences concerning CO_2 emissions and nuclear energy use. Thus, the main differences in the results are due to direct land occupation. The methods values organic land occupation much better than integrated production, which is the reason that organic products are shown to be better from an environmental point of view. Differences in yield also have an important influence.

Fig. 5.15 Main pollutants in the LCIA of carrots with the ecological footprint method



5.4.5 Summary of observations

In Table 5.2 we summarise the main observations from the case study on vegetables.

Tab. 5.2 Summary of main observations for the investigated criteria in the case study for vegetables

Criteria	Spinach (fresh, chilled, frozen), different scenarios for use phase, variation in agricultural production of carrots.
Functional unit and life cycle stages	Environmental information should be provided for the full life cycle per kg of product (this allows a direct comparison with other types of spinach) and for the life cycle until the shop per packaging size (this allows to see the influence on the personal balance). The definition of a functional unit that would allow for a direct comparison of spinach with other types of vegetables or food does not seem to be feasible, because it is difficult to give a good yardstick that can describe the function of a vegetable.
Product category rules	How to deal with variations between suppliers, within season or over years. Modelling guidelines for emissions in agricultural production. Inclusion of refrigeration in distribution. Electricity mix to be used for modelling of refrigeration (Swiss or European) will influence the results. Standard assumptions for refrigeration and cooking in the household. Standard assumptions for preparation (cooking time and type). Inclusion of losses and wastes from field to pot. Levels of decision-making addressed with the environmental information.
Actor responsible for calculation	The producer does not know the impacts of distribution, which depend on the specific refrigeration systems. Thus, it would be better to consider the distributor as the responsible actor for calculation. However, this would complicate the provision of information.
Differences between LCIA methods	Different methods do not differ concerning the overall conclusions if the full life cycle of processed vegetables is considered. However, the importance of single inputs and outputs vary, which would lead to different recommendations for product category rules. There are important differences concerning the assessment of agricultural production patterns leading to quite different conclusion depending on the LCIA method used. The evaluation shows that there might be some obstacles in using ecological scarcity and Impact 2002+ for the assessment of products where the agricultural stage is important. Variations in pesticide and copper use as well uncertainties in the characterisation of these substances have major implications for the results. The ecological footprint seems to be too simple concerning the difference between organic and other production. In this specific case, ReCiPe would provide more stable results, with a fact based differentiation and less workload needed for the assessment because for pesticides rough assumption would be sufficient.
Workload	The workload of an environmental impact assessment of vegetables is dependent on the level of details that shall be distinguished. This again, is dependent on the level of decision-making addressed. We roughly estimate the workload for the basic LCA of three types of spinach for an experienced LCA consultant at about 15 days. About 3 more working days are necessary to make further differentiations of variants of the product. The workload is considerably higher if variations in pesticide and copper use need to be taken into account in detail. On the other side, using the ecological footprint would reduce the workload for the inventory analysis considerably.
Importance of stages and demands on data collection:	
Production and packaging	Mainly important for comparison of fresh products. For chilled and frozen products less important. Specific data need to be investigated by the farmer if there should be a differentiation between spinach from different producers. Losses and wastes need to be investigated in case of freshly sold crops (e.g. spinach) and for comparison of fresh and conserved vegetables.
Distribution	Packaging is not important. There might be quite different impacts due to chilling and cooling. Therefore, specific data need to be investigated by the distributor for energy use of their cooling devices.
Delivery	Not important. Standard assumptions are sufficient.
Use phase	Quite important. Main influence by the consumer. Recommendations for the consumer are necessary in order to influence their behaviour. Average figures are difficult to investigate because user behaviour might show quite important differences. Generic assumptions for the use phase might lead to misguiding results e.g. for comparing fresh, chilled and frozen product.
End-of-life treatment	Not important.

Criteria	Spinach (fresh, chilled, frozen), different scenarios for use phase, variation in agricultural production of carrots.
Levels of decision-making and accuracy of investigation	The possibility to show differences between similar products is quite dependent on the level of decision-making that needs to be addressed. Good differentiation if life cycle is modelled until the shop. No differentiation possible if use phase is taken into account because of large possible variations in user behaviour.
Full consumption and food consumption. DML 7-9	Generic assumptions for vegetables are sufficient. It is not necessary to investigate spinach in detail.
Comparison of different types of vegetables. DML 5-6	Not feasible because functional unit for different vegetables (spinach vs. broccoli) is difficult to define.
Product variants: fresh, chilled and frozen spinach. DML 3-4	Generic data for three types of spinach conservation based on detailed LCA would be sufficient for information at shop. Difficult if information should cover the whole life cycle.
Comparison of spinach products from different producers or distributors. DML 3-4	Possible if some specific data are collected for agricultural production and distribution. Information should be provided "at shop" or producers have to agree on generic assumptions for the use phase.

5.5 Case study on textiles

5.5.1 System boundaries

So far not much background data is available in the ecoinvent database concerning the production patterns of textiles. The case study on textiles compares two T-shirts. One T-shirt is made of cotton and has a weight of 250 grams (Althaus et al. 2007; Classen & Jungbluth 2002). Therefore at least some background data of Chinese production are available. It is assumed that a cotton T-Shirt costs approximately 30 Swiss Francs.

For the second case we assume a synthetic T-shirt made of polyethylene based on (Walser 2009). The weight is 130 g per T-Shirt. It is assumed that a polyester T-Shirt costs approximately 40 Swiss Francs.

The weight of T-Shirts is based here on own measurements for only four T-Shirts with XL-size. It is quite variable and can depend on the functionality. Here casual cotton T-Shirts and more lightweight polyester Shirts for cycling and trekking have been weighted. According to other measurements, the weight might also be in the same order of magnitude e.g. for children clothes.[21]

The distribution and selling of clothes is estimated based on four environmental reports of large warehouses (C&A 2008; H&M 2004; 2005; KarstadtQuelleAG 2005). The energy consumption, water and packaging use is calculated per Swiss Franc. Infrastructure of the clothing stores is not included due to lack of information.

Also for marketing activities, so far, no data are available. Marketing, including advertisements in TV, printed media and internet as well as the preparation e.g. of photographs is considered to be of potential relevance especially for high priced products.

Delivery to the household is not included in the assessment. This could be relevant in case the clothes are bought in shops that are reached by car.

It is assumed that both T-shirts are washed 100 times during their life cycle. Data for the washing are available from an internal study (Faist Emmenegger & Frischknecht 2004). It is assumed that both T-shirts are disposed of in a municipal incineration after their use phase.

The production of the two example products stands for simple products and not for high-quality products such as outdoor clothes nor high priced clothes.

[21] Personal communication, Steffanie Hellweg, ETH Zürich, 26.1.2010.

5.5.2 Comparison with different LCIA methods

Fig 5.16, Fig 5.17 and Fig 5.18 show the most important impact categories in the LCIA with different methods.

Within an evaluation with the ecological scarcity method (Fig 5.16) the cotton T-shirt causes higher environmental impacts than the synthetic one. An important parameter for the comparison is the weight of T-Shirts that can be quite variable. Thus, this rough evaluation should not be interpreted as a general advantage of one material over the other.

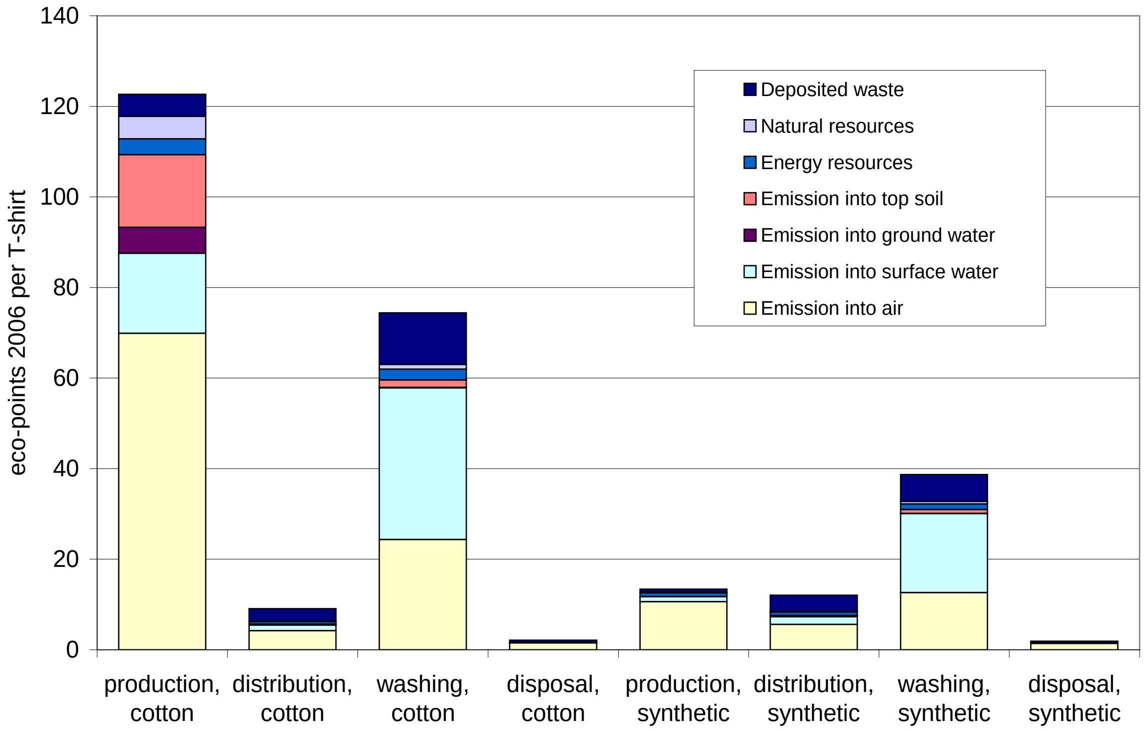
Production is more important than the use phase in case of the cotton T-shirt. The influence of distribution is relatively small. Disposal is not important at all. Environmental impacts of the production of the cotton T-shirt are caused to a large extent by electricity consumption in China causing CO_2, SO_x and NO_x emissions. Another important factor are emissions due to agricultural cotton production, e.g. pesticides.

In contrast to the cotton T-shirt, the most important phase in the life cycle of synthetic T-shirts is the use phase. Production and distribution exhibit about the same burdens with regard to synthetic T-shirts. Again the production in China is relevant but also the relatively high electricity consumption of clothing stores influences the result considerably. Compared to the production and distribution with indirect emissions, the disposal of the T-shirt is more relevant due to direct CO_2 and dioxin emissions during incineration.

Environmental impacts of washing are partly dominated by phosphorus emissions during the production of detergents and the direct electricity consumption. Thus, this result might change if another composition of the washing powder would be taken into account. The electricity consumption of the washing machine is also important. The difference between cotton and synthetic washing is due to different T-shirt's weight. Other possible differences e.g. concerning temperature or frequency are not taken into account.

It has to be noted that the generic characterisation factor for water consumption has not been differentiated regionally. If cotton is grown in dry areas, this factor might increase considerably and then water use might be a further important aspect for natural materials (Frischknecht et al. 2009a; Pfister et al. 2009).

Fig. 5.16 Most important impact categories comparing one usage of textiles with regard to ecological scarcity 2006



In Fig 5.17 we evaluate the environmental impacts with the ReCiPe method. The overall conclusions are similar to an evaluation with ecological scarcity. An important aspect for the washing is the issue of land transformation, due to the use of palm oil in the manufacturing of detergents.

Fig. 5.17 Most important impact categories comparing textiles with regard to ReCiPe (H,A)

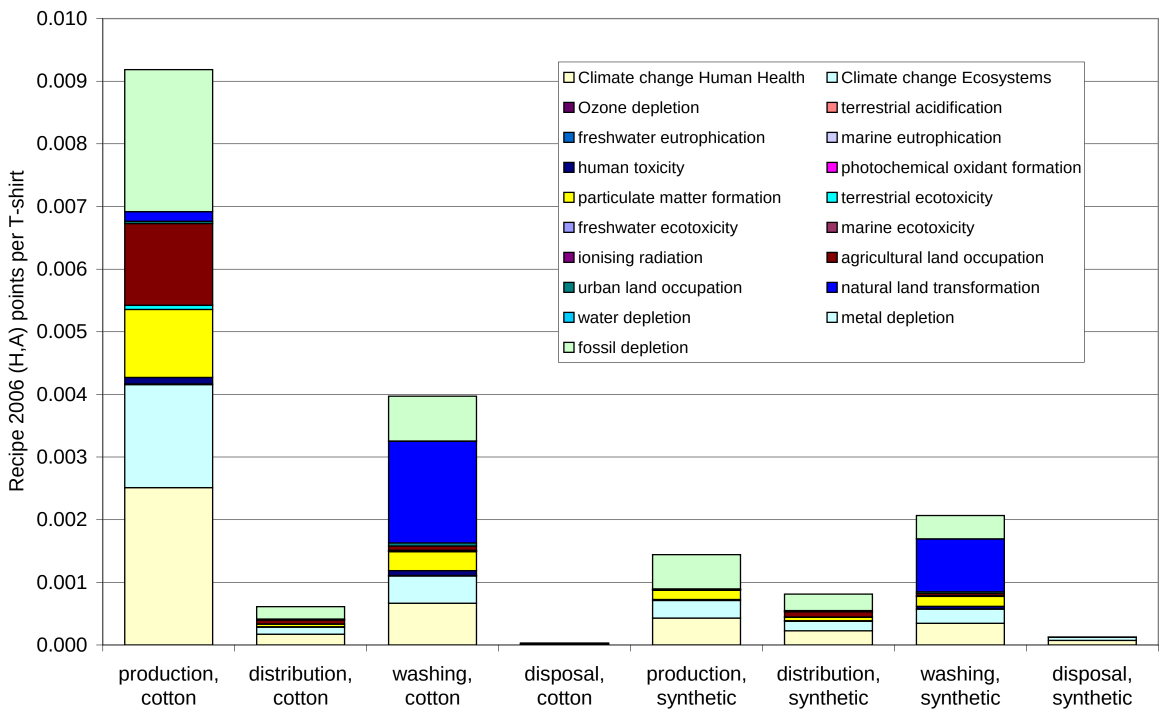
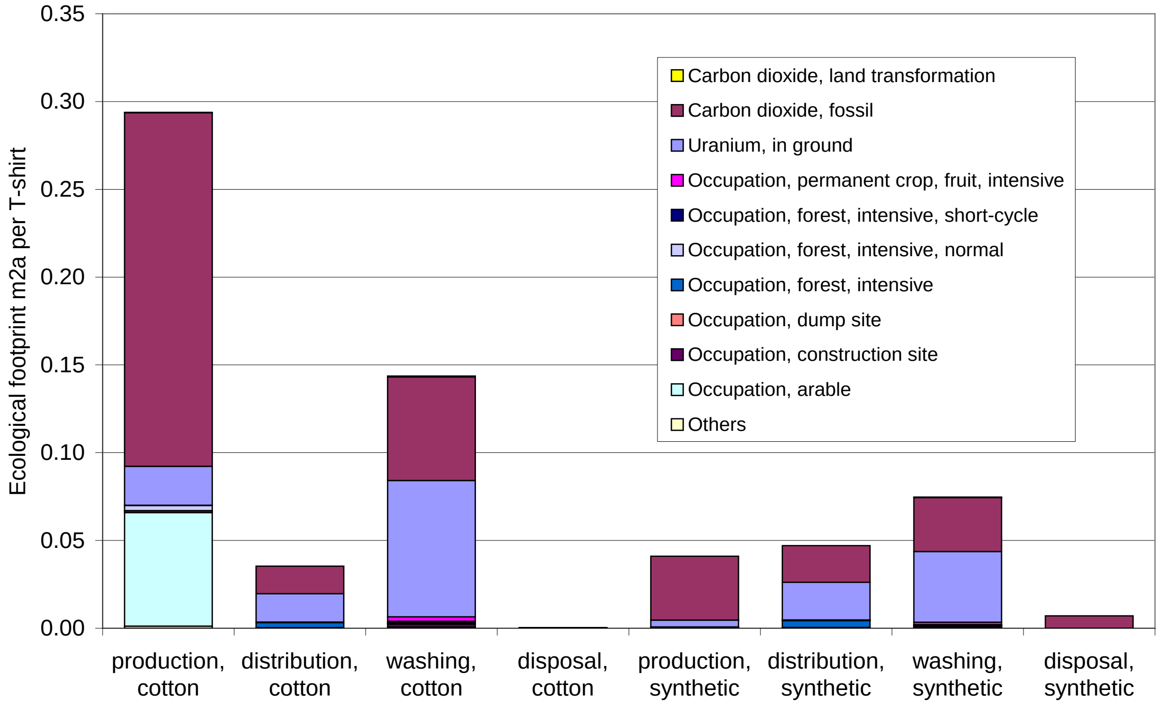


Fig 5.18 compares the environmental impacts with the ecological footprint. Here, too, general conclusions are similar to those with the other methods. The T-shirt made from natural materials has higher impacts

than the one made from fossil materials, due also to the land occupation for cotton growing. Washing is important mainly due to the electricity consumption.

Fig. 5.18 Most important impact categories comparing textiles with regard to the ecological footprint



5.5.3 Summary of observations

In Table 5.3 we summarise the main observations from the case study on textiles.

Tab. 5.3 Summary of main observations for the investigated criteria in the case study for textiles

Criteria	T-shirt made from cotton and synthetics
Functional unit and life cycle stages	Defining the functional unit for textiles is quite crucial for a comparison. Showing impacts per kg will be difficult to interpret and it will not be possible to compare different products. Showing results per piece (e.g. one T-shirt) can serve a little bit better, but still important differences concerning the durability or use time (how often can it be worn or when will it be thrown away because being out of fashion), the use phase (how often and how must it be washed) or the purpose (e.g. sport clothing versus business clothing) are not covered. Thus, it is difficult to define a functional unit, which fairly allows the comparison of all types of clothes. Washing is an important factor in the life cycle, but it depends on several aspects such as type of textile, frequency of washing, temperature, washing machine and detergent used. Thus, it will be difficult to include washing in a meaningful way, which allows on the one side a differentiation between aspects influenced by types of clothes and behavioural aspects.
Product category rules	Modelling guidelines for agricultural production. Guidelines for modelling of washing (temperature, frequency, standards for electricity and washing powder consumption). Inclusion of distribution and marketing in the assessment. Background data for textile production processes in overseas and waste treatment processes. Assumptions for end-of-life (we propose to consider incineration in order to take into account material differences even if clothes quite often have a second life cycle).
Actor responsible for calculation	Textiles are manufactured in several stages by different actors. Distribution and marketing can have an important influence. Thus, the distributor of the final product should be responsible for the environmental information.
Differences between LCIA methods	Different methods do not differ concerning the overall conclusions, but there was only limited information available for the case study. However, the importance of single inputs and out-

Criteria	T-shirt made from cotton and synthetics
	puts vary which would lead to different recommendations for product category rules. There are important differences concerning the assessment of agricultural production patterns leading to quite different conclusions depending on the LCIA method used.
Workload	The workload of an analysis for a specific product seems to be quite high. The production chain is shared by several actors. Part of the production is normally located overseas, which will complicate data acquisition. There are several different types of clothes on the market and so far there are not many generic background data e.g. in the ecoinvent database available. We roughly estimate the workload for the LCA of one type of cloth for an experienced LCA consultant at about 15-20 days if the work is assisted by manufacturers. If environmental information about textiles should be provided, it is quite crucial to extend the number of background datasets available. This should cover production of raw materials e.g. cotton in several countries, production of synthetic fibres, small parts (e.g. zipper, buttons), important processing steps, electricity generation in countries such as India, coverage of specific emission patterns in economies with lower standards in regulations, waste and effluent discharge in developing countries, etc. Also for distribution and marketing some background data would help for the necessary calculations.
Importance of stages and demands on data collection:	
Production and packaging	Quite important. Several processing steps. Regulations on emissions might be less strict in overseas countries. Only few background data available.
Distribution	Has some importance especially for high price products due to luxurious shops (more space) and advertisement efforts (not clear if they are really higher for high price products). Also product transports by air can raise the environmental impacts of a specific cloth considerably.
Delivery	Not important. Standard assumptions seem to be sufficient.
Use phase	Quite important. Influenced by the type of cloth as well as by the consumer. Recommendations especially on washing frequency, occupancy of the machine and temperature for the consumers are necessary in order to influence their behaviour. Average figures are difficult to investigate because user behaviour might show important differences. Similar generic assumptions for the use phase might lead to misguiding results e.g. for products that can be washed with different temperatures.
End-of-life treatment	Should be accounted for with standard assumptions on incineration to cover differences between natural and synthetic fibres.
Levels of decision-making and accuracy of investigation	The possibility to show differences is quite dependent on the level of decision-making that needs to be addressed. Good differentiation possible if life cycle is modelled until the shop. Differentiation more difficult if use phase is taken into account considering the specification of the textiles.
Full consumption. DML 9-8	Generic assumptions for production until the shop for general types of textiles are sufficient.
Different types of textiles (e.g. trousers, shirts, underwear). DML 7	Difficult to make generic differentiation. Comparison not meaningful, because one product type cannot be replaced by the other.
Comparison of different types of trousers (jeans, synthetic, etc.) or specific products. DML 5-6	It is necessary to investigate each product in detail for the whole production chain.
Product variants: e.g. different colours. DML 3-4	So far, not clear if there will be relevant differences e.g. for different colours, sizes, etc.
Comparison of washing, detergents, etc.. DML 1-2	Not relevant for environmental information for textiles.

5.6 Case study on electricity supply

5.6.1 System boundaries

This case study deals with aspects of electricity supply to consumers. We compare some types of electricity generation from an environmental point of view. Data are taken directly from the ecoinvent database (ecoinvent Centre 2009) and describe current technologies. In principle, product information should also show the impacts of distribution. This is not accounted for here, as the main aspect is losses. So far, we do not have sufficient data to model losses separately for different types of electricity generation or for different suppliers.

Plant-specific information about electricity supply has been developed within the labelling scheme for renewable energy. This makes the same generic assumption for the distribution of all types of electricity (Jungbluth et al. 2010b).

5.6.2 Comparison with different LCIA methods

Fig 5.19, Fig 5.20 and Fig 5.21 show the ten most important emissions and resource uses in the LCIA with different methods. In all methods, carbon dioxide is an important factor. However, for other emissions and pollutants there are some differences concerning their weight in the total results.

The ecological scarcity method puts a high weight on some aspects of nuclear power generation. For renewable technologies, further aspects are NH_3 and N_2O emissions (biogas), heavy metal emissions (photovoltaics) and dioxin emissions due to materials used for wind power plants. Renewables show in general a lower environmental impact than fossil and nuclear technologies.

The evaluation with ReCiPe shows considerable differences concerning the judgement on nuclear power. Impacts of this technology are quite low because none of the specific emissions or resource uses is considered to be of specific importance. The resource use is considered by the extraction costs and not by the energy content. Thus, it counts much lower for nuclear compared to fossil resources. The storage volume for nuclear waste is not considered as relevant resource use. For biogas, again N_2O and NH_3 are important emissions.

An evaluation with ecological footprint shows again a clear preference for renewables compared to non-renewable supply. Surprisingly, wood-fired power plants do not have an important contribution of land occupation.

The differences in underlying value judgements lead to important differences in the interpretation and comparison of different types of electricity generating technologies especially when comparing nuclear and renewable technologies. For the detailed evaluation of similar technologies, e.g. different types of photovoltaics, there are not such different outcomes.

Fig. 5.19 Most important emissions and resource uses comparing electricity generation with regard to ecological scarcity 2006

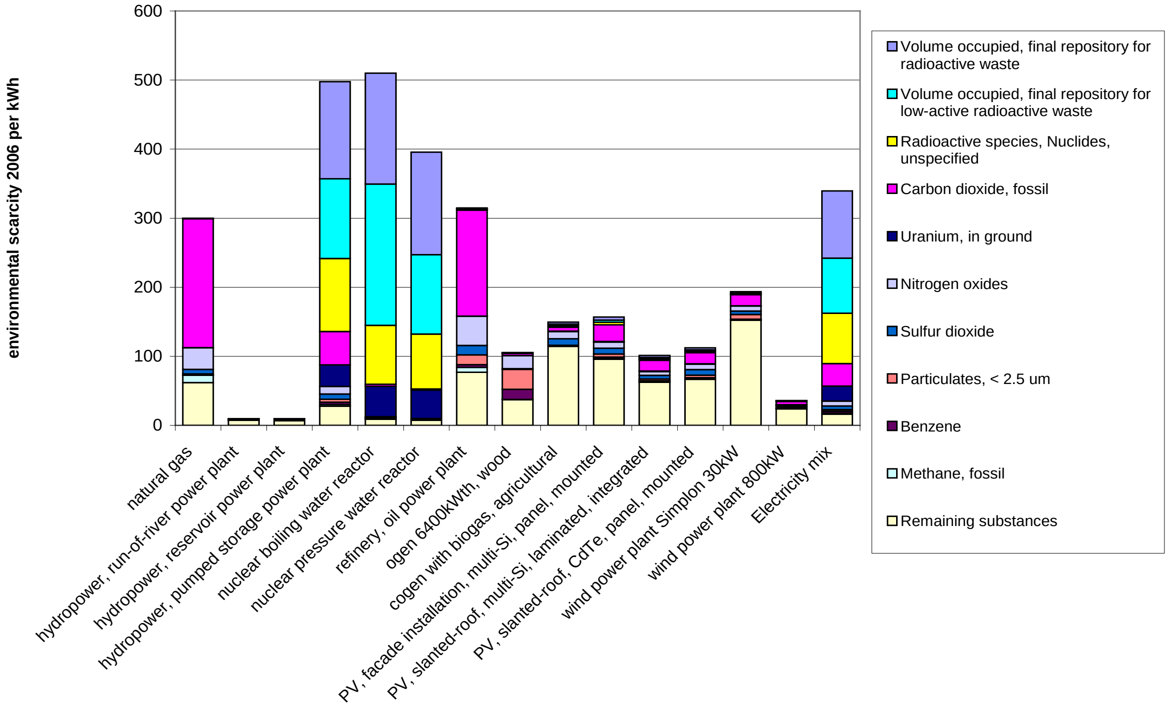


Fig. 5.20 Most important emissions and resource uses comparing electricity generation with regard to ReCiPe (H,A

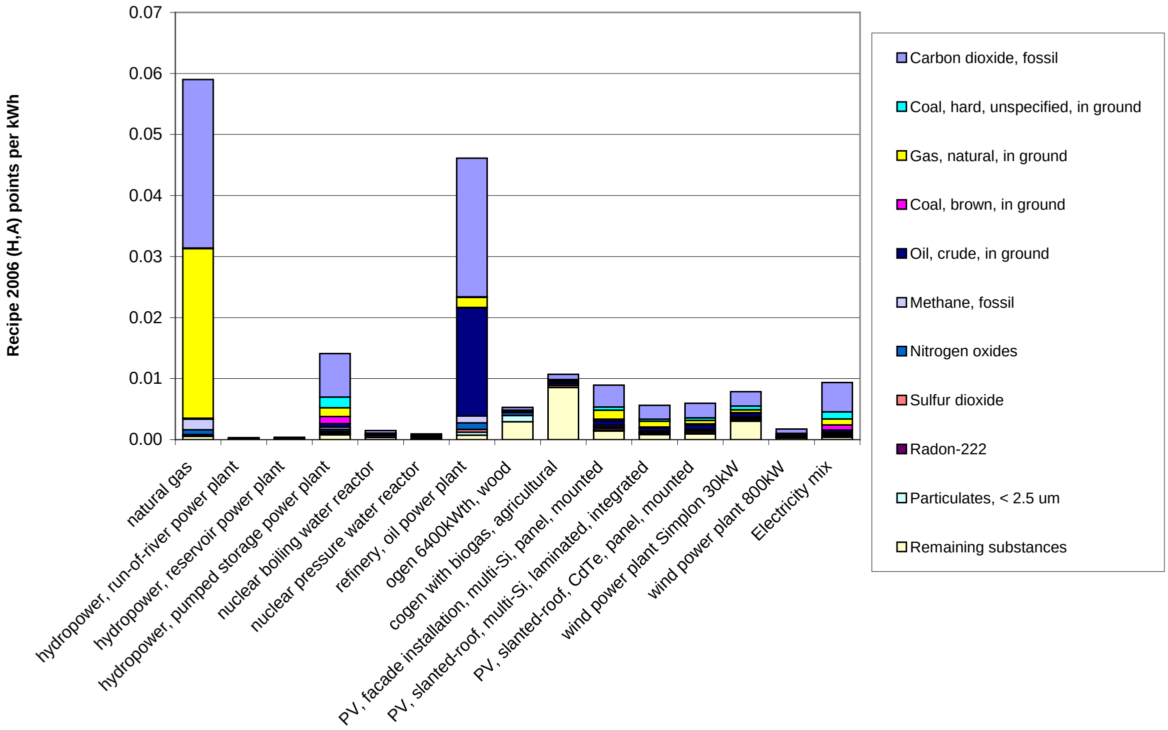
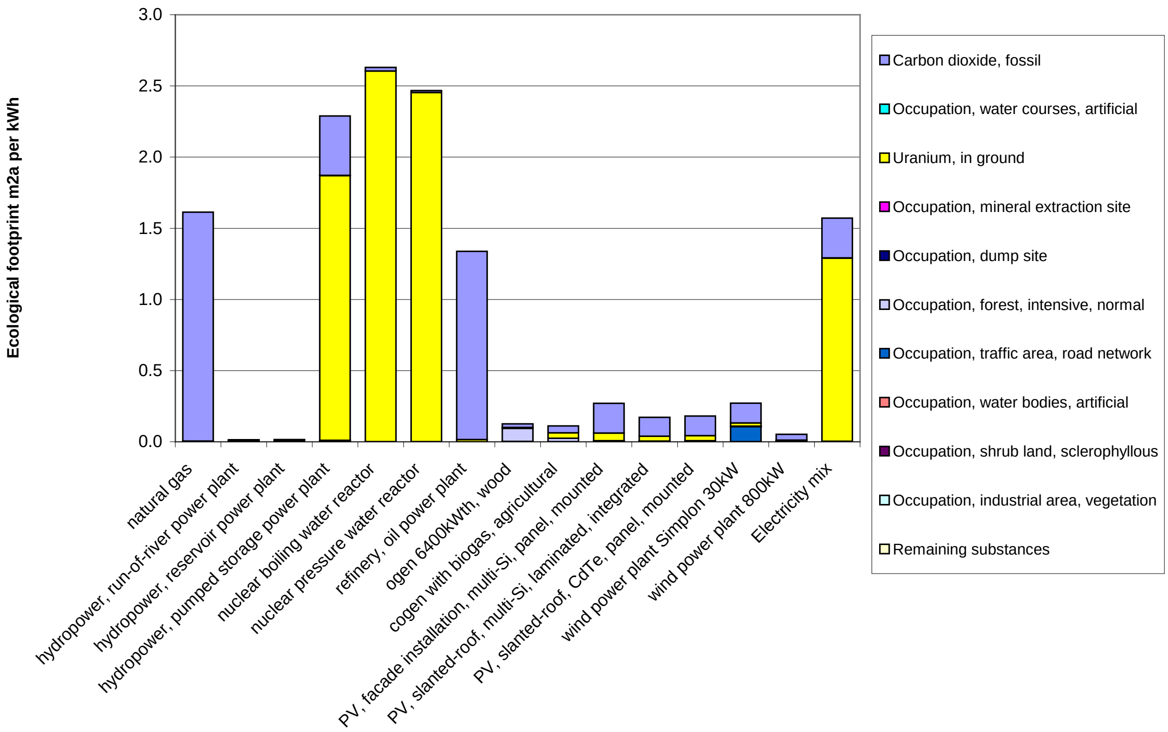


Fig. 5.21 Most important emissions and resource uses comparing electricity generation with regard to the ecological footprint



5.6.3 Summary of observations

In Table 5.4 we summarise the main observations from the case study on electricity supply.

Tab. 5.4 Summary of main observations for the investigated criteria in the case study on electricity

Criteria	Electricity production, different types of power plants
Functional unit and life cycle stages	Environmental information should be provided for the provision of one kWh electricity to the consumer. This includes production and distribution. We do not see a need or a relevance of including the use phase for consideration at most DMLs.
Product category rules	PCRs have been developed and they need to be revised in case a single-score LCIA method should be used (PCR CPC 17 2007). The full infrastructure of the power plant and the supply network should be taken into account. It is necessary to provide guidelines for the evaluation of losses during distribution, which might be quite different depending on the voltage level and final point of sale. Therefore, data have to be provided by the network operator. There should be guidelines how to deal with electricity trade and how to distinguish different electricity products sold to the consumer. General guidelines how to educate consumers on electricity saving.
Actor responsible for calculation	The network operator or the company selling the electricity to the consumer should be responsible for the provision of the environmental information for certain “electricity products” that can be ordered by the final consumer.
Differences between LCIA methods	Different LCIA methods differ considerably while comparing nuclear, fossil and renewable power. Each method in itself seems to be consistent. However, there are modelling choices that influence the outcome of the comparison. These choices seem to be more a value judgement and not necessarily a fact that can be clearly evaluated with a scientific method. There are also some further differences concerning the inclusion of certain emissions and resource uses, which have a less pronounced effect for the results.

Criteria	Electricity production, different types of power plants
Workload	There are already simplified models available for the evaluation of single power plant technologies. Such models allow a reasonably accurate calculation based on view key-parameters, which have to be evaluated beforehand in a detailed LCA. The workload for such a model is estimated at about 5-10 days per technology and would allow a plant specific consideration. Furthermore data have to be evaluated for the network (ca. 3-5 days per network operator).
Importance of stages and demands on data collection	
Production	Needs to be evaluated for the specific power plants including infrastructure and fuel supply chain.
Distribution	At least losses should be evaluated for the network operator.
Delivery	Included in distribution. Different levels of voltage need to be distinguished.
Use phase	Electricity can be used for quite different types of appliances. The production of these appliances cannot be considered for the product information. Nevertheless, it would be suggested to provide also information how to reduce electricity use to the consumer. The use phase would be important if a specific application e.g. use of electricity for heat pumps or direct heating should be compared with e.g. oil heating. In this case, the function and the appliances need to be considered.
End-of-life treatment	Waste heat could be an issue e.g. in data centres. Recommendations how to reuse waste heat should be elaborated.
Levels of decision-making and accuracy of investigation	
Full consumption. DML 9	Generic assumptions on country specific electricity mix are sufficient.
Need field energy, e.g. heating or mobility. DML 8	For comparison with other types of energy supply it would be necessary to provide information for certain functional uses, e.g. heat provided by different types of heating. Therefore, the unit kWh of electricity is not sufficient and further investigation on the use phase would be necessary.
Supply technologies. DML 7	Generic assumptions on production technologies are sufficient.
Comparison of different types of electricity production. DML 5-6	It is necessary to investigate plant, network and portfolio mix specific data.
Product variants: daily and seasonal variation. DML 4	There might also be a daily or seasonal variation in electricity mixes. This might be important for certain types of electricity uses (e.g. refrigeration, heating, electric mobility). In order to support decisions on this level it would be necessary to provide information on a timely differentiated scheme, which would increase the workload considerably.
Further details. DML 1-3	Seems not to be applicable.

5.7 Case study on mineral water

5.7.1 System boundaries

The case study on mineral water is based on a detailed LCA comparing mineral water and tap water from an environmental point of view. Within this study several scenarios concerning packaging, transportation and user behaviour have been evaluated (Jungbluth & Faist Emmenegger 2005). Here we focus on still mineral water and show the results for several scenarios.

5.7.2 Comparison with different LCIA methods

Fig 5.22, Fig 5.23 and Fig 5.24 show the environmental impacts concerning different aspects in the life cycle of mineral water in an LCIA with different methods. All impacts are shown per litre of still water. For the total result, impacts of production, distribution, delivery and use phase have to be summed up for the specific type of production chain.

The left side shows the impacts of water bottling and the packaging. There are considerable differences concerning different type of packages. A one-way glass bottle has the highest impacts. It is possible for the producer to analyse these impacts for the specific product and to provide information about this.

The second section shows the impacts of distribution. Quite important differences arise concerning the transport distances and transport modes used for transporting the mineral water to the shop. In practice, it might be difficult to provide information about this directly on the product because the impact is quite dependent on the transportation chain used for the delivery to a specific supermarket.

Also transporting the mineral water home is sometimes an important aspect, especially if a private car is used for shopping. Refrigeration can be important in the use phase.

Finally, the figures give an estimation of the total impacts from the life cycle in an average scenario.

The different LCIA methods differ slightly concerning main conclusions that can be drawn. This is mainly due to different results for electricity supply. Thus, ReCiPe gives less weight to the consumption of electricity e.g. in the use phase with refrigeration.

Fig. 5.22 Most important emissions and resource uses comparing electricity generation with regard to ecological scarcity 2006

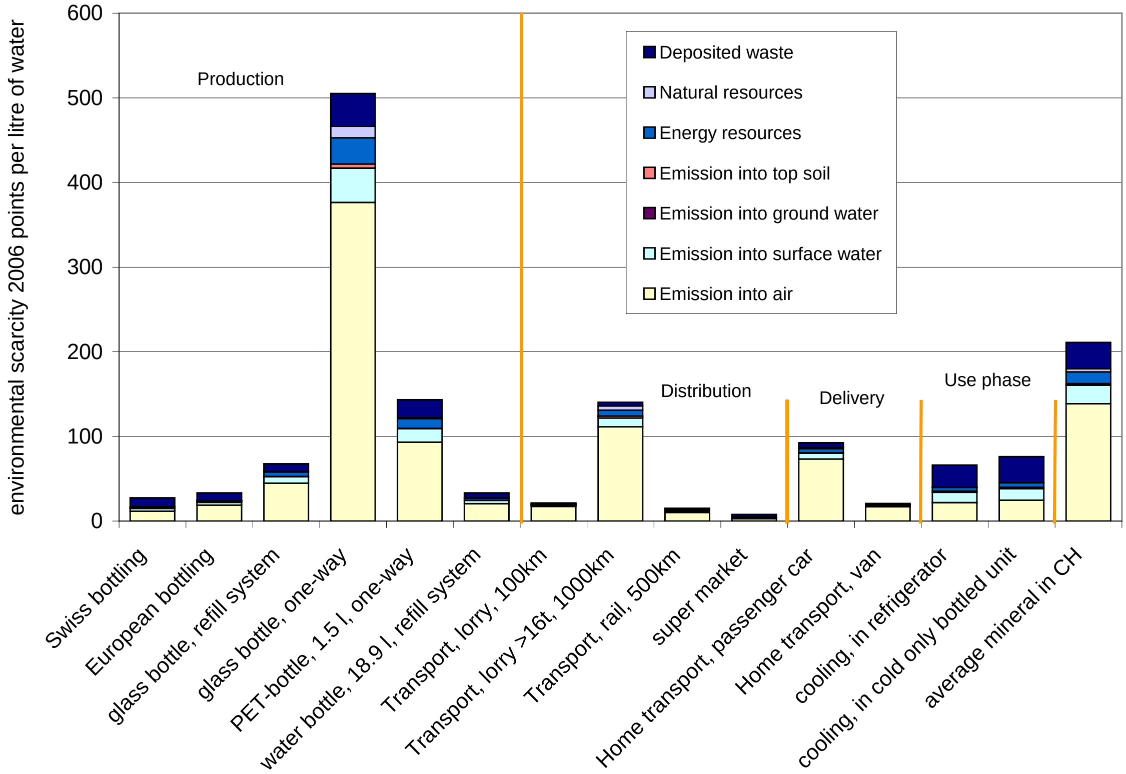


Fig. 5.23 Most important emissions and resource uses comparing electricity generation with regard to ReCiPe (H,A)

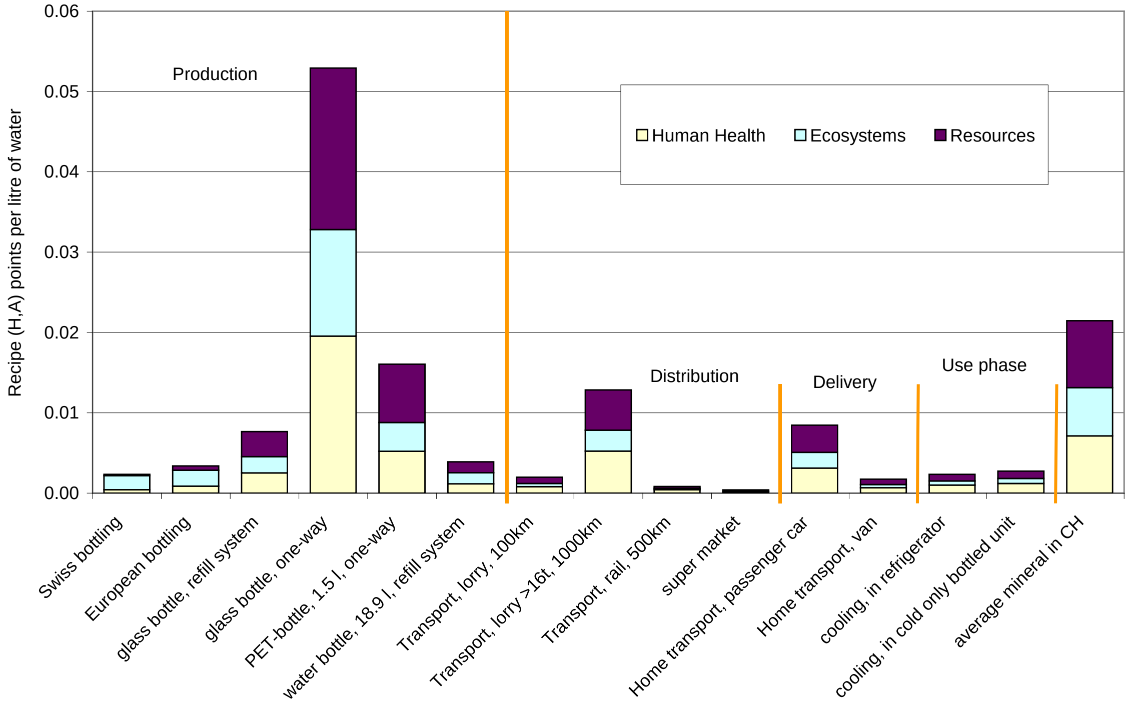
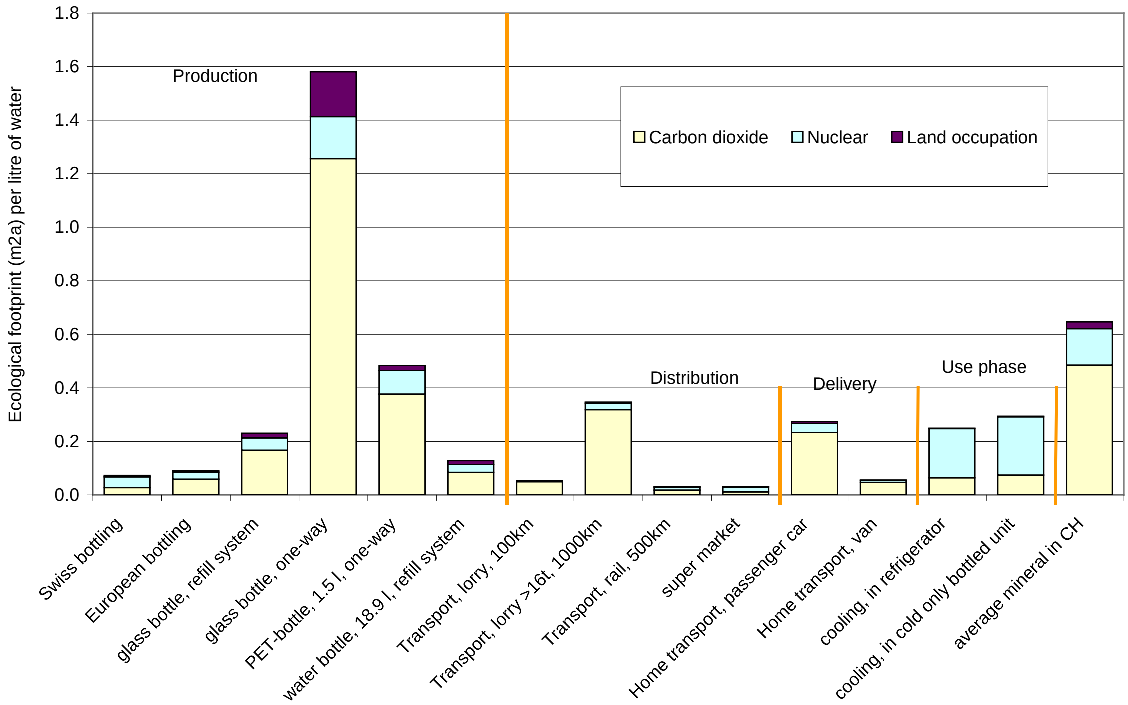


Fig. 5.24 Most important emissions and resource uses comparing electricity generation with regard to the ecological footprint



5.7.3 Summary of observations

In Table 5.5 we summarise the main observations from the case study on mineral water.

Tab. 5.5 Summary of main observations for the investigated criteria in the case study on mineral water

Criteria	Mineral water, different scenarios
Functional unit and life cycle stages	Environmental information should be provided for the life cycle until the shop per packaging size (this allows to see the influence on the personal balance and to compare different types of mineral water). It does not seem to make sense to include the use phase, as one cannot recognise an influence of the product on consumer behaviour (e.g. refrigeration or not). The disposal of the packages (end-of-life) should be included. But this would sometimes lead to unclear system boundaries. The definition of a functional unit that would allow for a direct comparison of mineral water with other types of beverages or food does not seem to be feasible, because it is difficult to give a good yardstick that can describe the function of it.
Product category rules	Investigation of transportation from factory to point of sale. Standard background data for transport modes and packages if no foreground data are available. Assumptions for end-of-life disposal routes, recycling rates and reuse of bottles. Levels of decision-making addressed with the environmental information.
Actor responsible for calculation	Producers do not know the impacts of distribution, which depend on the transport distance. Thus, responsibility of distributor would be better, but would complicate the provision of information.
Differences between LCIA methods	Different methods do not differ much concerning the overall conclusions.
Workload	We roughly estimate the workload for the basic LCA of one mineral water for an experienced LCA consultant at about 3 days. It would be feasible to develop key-parameter models, which allow for a simplified calculation of the packages and transports in distribution.
Importance of stages and demands on data collection	
Production and packaging	Quite important differences between different types of packages. Bottling of lower importance. There might be some relevance of the electricity used and of cleaning refilled bottles.
Distribution	Transport between manufacturer and final point of sale is quite important and needs a detailed investigation.
Delivery	Might be important, especially if private car is used.
Use phase	Can be important. Main influence by the consumer. Recommendations for the consumer are necessary in order to influence their behaviour. Average figures are difficult to investigate because user behaviour might show quite important differences. We would recommend not including the use phase.
End-of-life treatment	Important for the packages. Disposal routes, recycling rates and take-back systems need to be taken into account.
Levels of decision-making and accuracy of investigation	The possibility to show differences between more or less similar products is quite dependent on the level of decision-making that needs to be addressed. Good differentiation if life cycle is modelled until the shop. No differentiation possible if use phase is taken into account because of large possible variations in user behaviour.
Full consumption and food consumption. DML 7-9	One generic assumption for average mineral water at shop would be sufficient.
Comparison of different types of beverages. DML 6	Generic assumptions for mineral water in different types of packages and from different origin are sufficient. But a functional comparison is not possible.
Product category mineral water. DML 5	Differentiation is necessary for the specific manufacturer, packaging and distribution.
Product variants: (un-)chilled, still or sparkling. DML 4	If offered chilled in the shop this might be relevant. Influence of carbonisation is quite small.
One product in different packages. DML 3	If mineral water from one source is available in different packages or packaging sizes, there might be important differences. These need to be evaluated in detail.
DML 2	Mainly relevant for the use phase, e.g. storage in the refrigerator.
DML 1	Not relevant.

5.8 Case study on cars

5.8.1 System boundaries

The case study on cars is based on ecoinvent data v2.01 and life cycle inventories for conventional cars as well as cars fuelled with biofuel or electricity (Frischknecht & Leuenberger 2009; Jungbluth et al. 2007a; Spielmann et al. 2007).

5.8.2 Analysis of results

For the case study on cars, we can distinguish five different stages of the full life cycle of a car. Stages 2 to 4 are part of the use phase, while 5 belongs to the end-of-life stage.

1. The production of the car
2. The operation of the car including fuel use and emissions
3. The maintenance of the car
4. The production, maintenance and disposal of road infrastructure
5. The disposal of the car

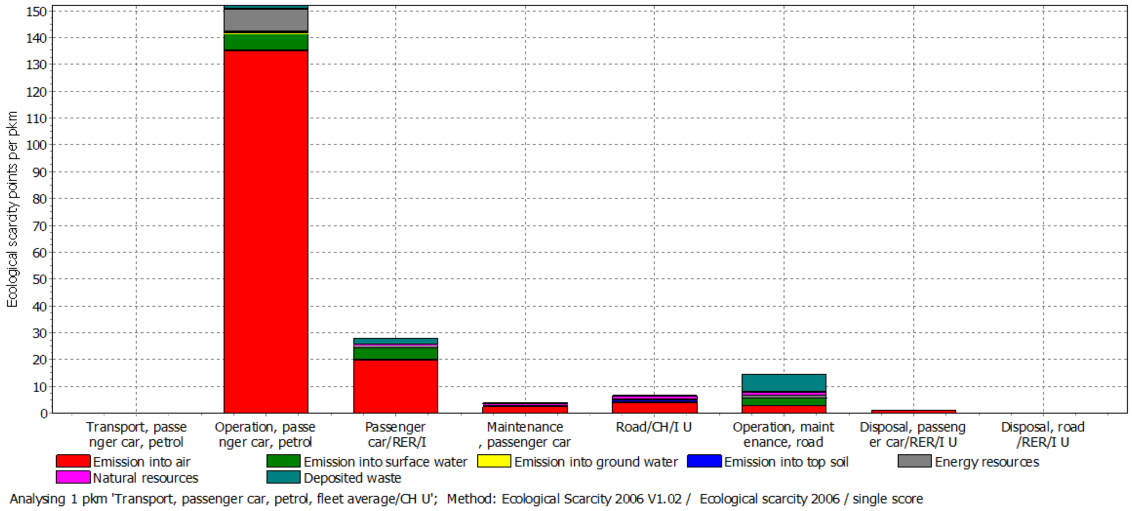
Fig 5.25 evaluates with the method ecological scarcity the environmental impacts of an average car driven in Switzerland. The operation of the car is the most important stage in the life cycle. It accounts for more than 70% of the environmental impacts. Second most important is the production of the car.

The question arising is: "Which environmental impacts do we want to show in the environmental information about a car?". From the car's life cycle, we can distinguish the above-mentioned stages. Moreover, we have to think about which part of the environmental impacts should be shown with which product (Table 5.6).

Tab. 5.6 Life cycle stages and allocation to products bought by the consumer

Life cycle stage	Information can be shown on which products?	Influencing factors and actors
Production of the car	Car	Car manufacturing
Operation including fuel use and emissions	Car, Fuel	Design of car (fuel consumption, emission standard), production of the fuel, user behaviour
The maintenance of the car	Car, Maintenance cost	Design of car, user behaviour
The disposal of the car	Car, Disposal cost	Design of car, user behaviour
The production, maintenance and disposal of road infrastructure	Car, Fuel (taxes), Taxes for car ownership	Weight and size of car, frequency of use

Fig. 5.25 Importance of life cycle stages for a car. Environmental impacts as ecological scarcity points per person-kilometre driven



Production of the car

So far we do not have sufficient data to make an evaluation of different production patterns for a car. But it is clear that there are differences concerning the environmental impacts during production that can be evaluated with an LCA. The main influencing factors will be the weight and type of materials used, the amount and energy used during production as well as environmental standards e.g. on emission abatement in the manufacturing plants. Some car producers have already evaluated the environmental impacts in case studies. Such an assessment can be quite complex due to the large number of production steps, suppliers and materials used.

Operation of the car

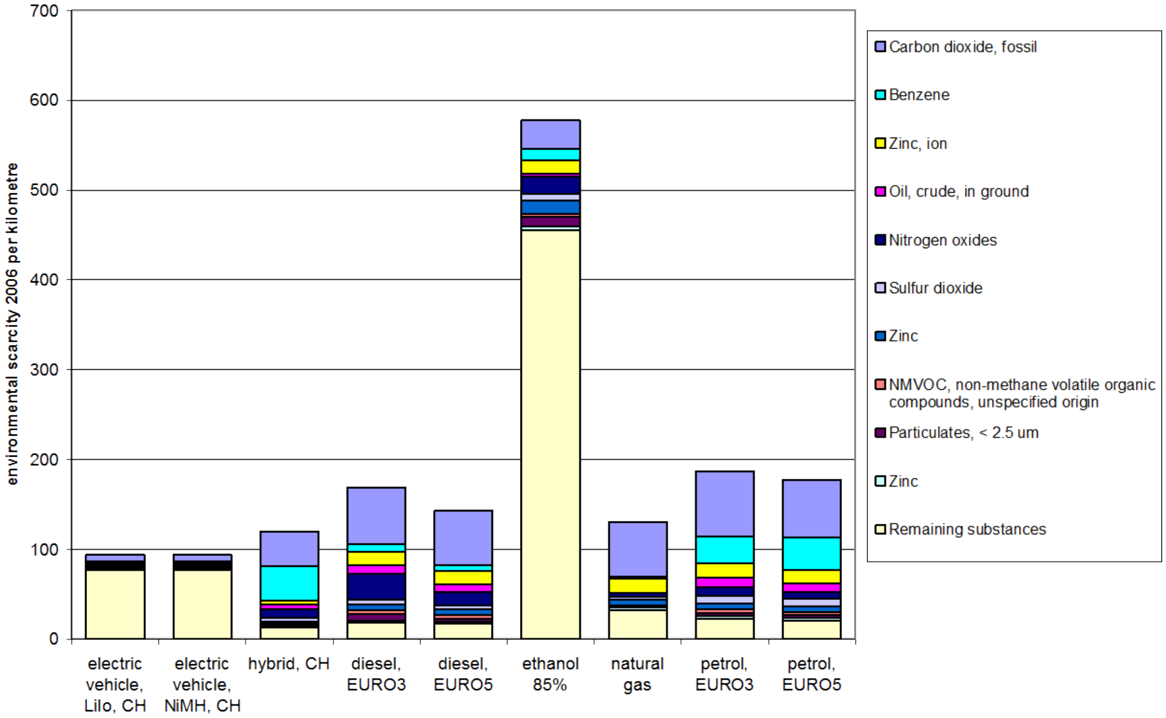
Fig 5.26, Fig 5.27 and Fig 5.28 show the ten most important emissions and resource uses in the LCIA with different methods. In all methods, carbon dioxide is an important factor. However, for other emissions and pollutants there are some differences concerning their weight in the total results. It has to be noted that the cars considered in this case study not only differ concerning the direct emissions, but also concerning the amount of fuel used per kilometre. Thus, e.g. differences between EURO 3 and 5 are also due to different amounts of fuel and thus different CO_2 emissions.

So far no information is available concerning the influence of auxiliary equipment such as air-conditioning. The real fuel use of cars is normally higher than the one measured in standard tests due to such electricity consuming appliances. For information about specific cars it seems important to include this part of environmental impacts as well.

We can observe some similar findings as in the case studies before. Within the ecological scarcity method, pesticides are highly important in the assessment of one exemplary agrofuel. This is why ethanol as a fuel shows higher impacts than other fuels. A detailed comparison of different crop-agrofuel pathways is available in former Swiss studies (Jungbluth et al. 2008; Kägi et al. 2007; Zah et al. 2007) and thus not discussed in detail here. With the ecological scarcity method benzene is an important direct emission that would need a detailed investigation in the life cycle inventory.

For the comparison of EURO standards mainly NO_x can have an important influence. Zinc emissions are due to tyre abrasion and thus they are not directly influenced by the fuel use or emission standard.

Fig. 5.26 Most important emissions and resource uses comparing operation of different cars with regard to ecological scarcity 2006



Electric cars show quite low environmental impacts if evaluated with the ReCiPe method (Fig 5.27) due to the reasons already discussed in the electricity case study. CO_2 and fossil energy resources are most important for conventional cars.

A comparison with the ecological footprint shows also considerably higher impacts for the example of an agrofuel due to the direct land occupation resulting from biomass cultivation. Differences between non-renewable energy sources are less pronounced (Fig 5.28).

Fig. 5.27 Most important emissions and resource uses comparing operation of different cars with regard to ReCiPe (H,A)

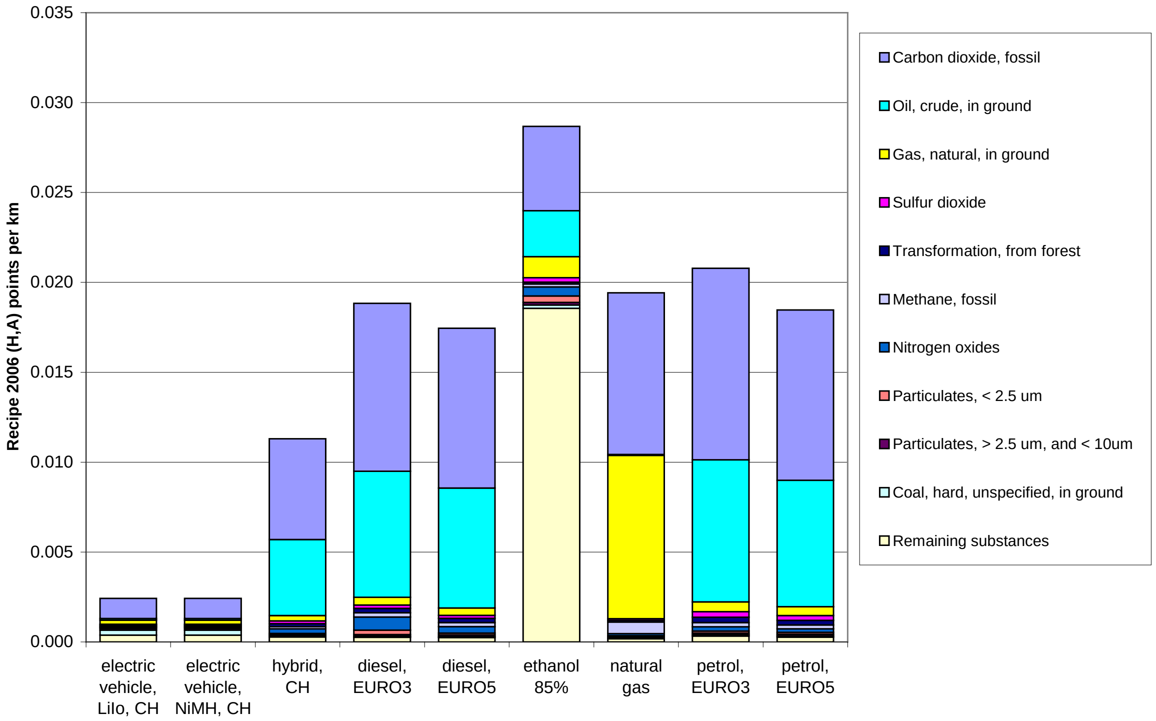
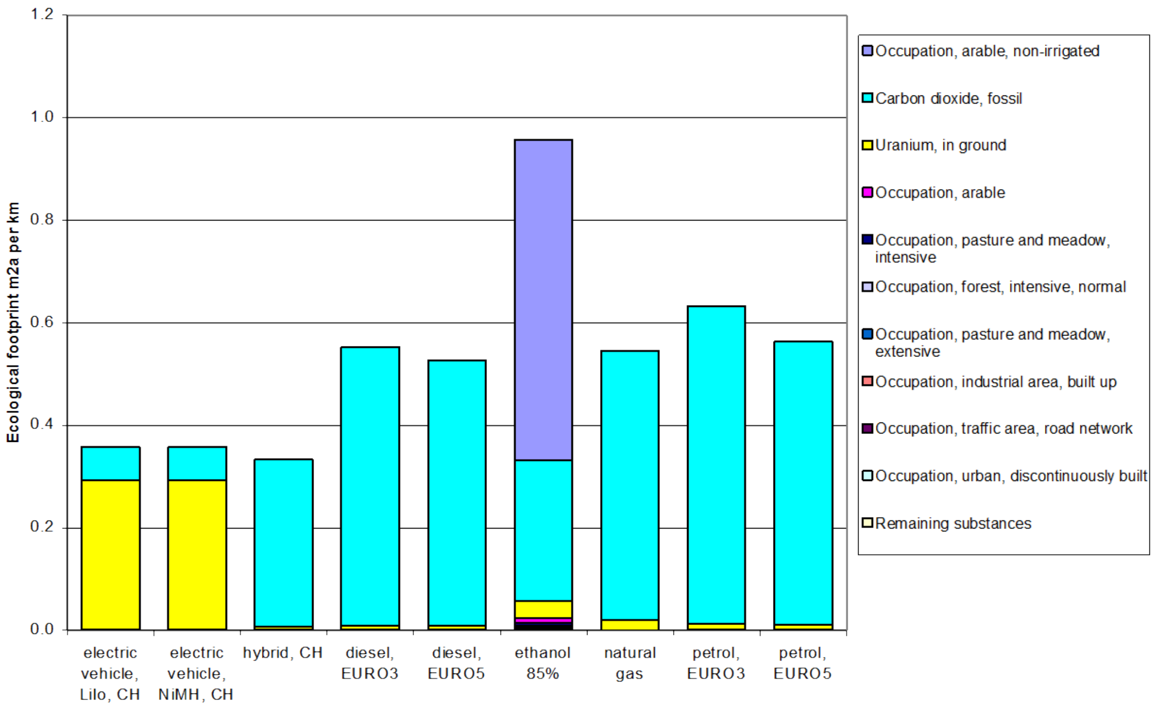


Fig. 5.28 Most important emissions and resource uses comparing operation of different cars with regard to the ecological footprint



Further stages of the life cycle

For the further stages of the life cycle such as production, maintenance and disposal of road infrastructure, we do not have detailed data in order to investigate important differences. These stages are not of major importance for the overall conclusions. Thus, we do not discuss them in more detail here.

5.8.3 Summary of observations

In Table 5.7 we summarise the main observations from the case study on cars.

Tab. 5.7 Summary of main observations for the investigated criteria in the case study on cars

Criteria	Life cycle of different types of cars
Functional unit and life cycle stages	Different cars can best be compared by the environmental impacts per kilometre driven. Form an environmental point of view, this should include at least production and operation of the car. It might be discussed also to include the number of seats and average occupancy in the assessment in order to allow a fair comparison between different sizes of a car, e.g. 2-seater or 7-seater.
Product category rules	The product category rules need to cover the following aspects: In how much detail should the production of the car be investigated. Which assumptions are taken for the car operation (fuel use, emission patterns). How to include fuel use for electricity generation in the car that is dependent on auxiliary equipment, e.g. air-conditioning. How to deal with flexible fuel cars. Standard assumptions for the production of the fuel. We propose to exclude the following stages: - Maintenance and disposal. - Use of road infrastructure based on size.
Actor responsible for calculation	The manufacturer of the car should be responsible for the provision of the environmental information. There is no important influence of the distribution chain.
Differences between LCIA methods	Different LCIA methods differ concerning electric, fossil and agrofuel powered cars. There are some further differences concerning the inclusion of certain emissions and resource uses, which have a less pronounced effect for the results.
Workload	The workload of investigating the production of cars seems to be quite huge. Some simplifications might be discussed with car manufacturers in order to reduce the workload for investigation. For the assessment of operation emissions and fuel use, clear guidelines have to be developed. Afterwards we estimate the workload not to be high compared to the one for investigating the production.
Importance of stages and demands on data collection	
Production	Needs to be evaluated at least for some important models of cars. Clear guidelines for accuracy versus simplification are necessary.
Distribution	Not important
Delivery	Not important
Use phase	The direct emissions and the fuel use are quite important for the assessment. Use of road infrastructure is of lesser importance.
End-of-life treatment	Detailed data are not always available. But it seems to be of minor importance as long as proper treatment is ensured.
Levels of decision-making and accuracy of investigation	
Full consumption and need field energy. DML 8-9	The car production and use phase should be considered separately in order to account also for the frequency of use. Generic assumptions for production of a car are sufficient. The annual amount of fuel used has to be known and EPI is calculated separately for this.
Mobility. DML 7	Generic assumptions should be made per transport service of a car compared to other types of mobility per person-kilometre. Thus, the functional unit is different from other DML.
Comparison of different types of cars. DML 5-6	It is necessary to determine producer specific information about the car's production and operation.
Product variants: auxiliary equipment bought with a certain type of car. DML 4	Information on auxiliary equipment (e.g. air-conditioning, electricity using features, etc.) needs at least to be considered in the data on operational fuel use and emissions.
Further details. DML 1-3	Seems to be not applicable or should be covered elsewhere (e.g. car washing and maintenance).

5.9 Correlation between LCIA methods

The correlation between LCIA methods for a range of products and services has been investigated in the literature (Huijbregts et al. 2006). However, this publication does not include the LCIA methods ReCiPe and ecological scarcity 2006. The publication shows that there is normally not a clear correlation between different methodologies. They highlight the different assessment of aspects such as nuclear power, land occupation, specific emissions of agricultural processes or process specific emissions in the manufacturing of plastics.

A publication examining the importance of capital goods in LCA also finds quite different results depending on the type of LCIA method used (Frischknecht et al. 2007a).

Some of the differences and sensitive areas which lead to different assessments for the same product have been discussed in the previous chapters.

5.10 Conclusions

Within the project's terms of reference, several questions were raised concerning the evaluation of the case studies. Here we provide some answers based on the evaluation of different types of products in case studies.

The detailed evaluation of agricultural production revealed some differences concerning the workload and uncertainties with **different LCIA methods**. The ecological scarcity method is difficult to apply for detailed agricultural production patterns as pesticide use is quite important. Investigating the use of pesticides for a range of single products in the necessary detail would be quite time consuming and would be also quite variable. Thus, in this case ReCiPe seems to be more appropriate to consider relevant differences on the one side. On the other side it is quite variable and makes it difficult to investigate specific aspects. Impact 2002+ and ecological footprint seem to be too much influenced by one factor only (copper emissions and land occupation, respectively). When investigating more generic data at higher DMLs such differences are less important.

Another important difference between LCIA methods is the assessment of energy from nuclear, fossil and renewable resources. With ReCiPe, nuclear energy is evaluated as quite favourable. The ecological scarcity method and the ecological footprint both assign higher impacts to the use of nuclear power. This seems to be a matter of subjective appraisals of the impacts considered in the assessment.

→ A decision needs to be taken on which LCIA method is to be used.

The choice of the LCIA method has implications for the LCI **workload**. Working with the ecological footprint would simplify data acquisition, as only a limited list of exchanges has to be considered. Evaluating environmental impacts with the ecological scarcity method is most demanding for data quality as several types of emissions and resource uses might be important.

Rules for the environmental product information can only be derived if the underlying question is clarified. Especially it needs to be clarified which **level of decision-making** should be addressed with the information. Depending on this level there might be quite different recommendations e.g. concerning the functional unit for the information.

→ A decision needs to be taken on which main questions are to be answered.

The **workload** for investigating a range of consumer goods depends on the level of accuracy that is intended, the LCIA method and the type of product investigated. This again depends on the **level of decision-making** to be addressed. For some product groups it might be feasible to develop key parameter models, which would allow an easy quantification of the environmental impacts. Electricity would be such an example. For other products, the workload is estimated to be considerable. Within the products investigated, textiles are considered the most complicated group. They are produced in several production stages, many of them outside Europe. So far, not much background data are available. Thus, there is also not much experience concerning possible simplifications. Also the detailed investigation of different car types can be quite time consuming. But car manufacturers may be able to develop simplified models for their production chain. As long as the detailed approach is not clear it is impossible to estimate an overall workload for investigating all consumer products.

The level of decision-making determines the level of detail that is necessary to collect data for a specific product. The lower the DML the higher is the workload for investigating necessary data for single products. But this workload also depends on the number of alternatives or the knowledge already available.

→ A decision needs to be taken on the DML to be addressed as the first goal.

Some simplifications for the approach could be elaborated once the basic questions set out above have been clarified.

The case studies show that there are specific issues for each type of product which need to be clarified in more detailed product category rules. This includes a pre-evaluation of the importance of different stages in the life cycle. So far we could not identify any product groups or services which in principle could not be investigated for an environmental product information.

In most cases, the producers should be responsible for elaborating the environmental product information. However, in some cases, e.g. mineral water or deep-frozen products, there might be an important influence of the distribution chain. Thus, producers and distributors should work together in order to derive reliable information about the environmental impacts caused by the product until it is in the shopping cart of the consumer.

6 Possible communication strategies

6.1 Introduction

Behind every environmental product information is a complex method for evaluating the environmental impacts of different products. However, to communicate the results it is necessary to simplify the message as far as possible without losing the precision that is essential to present credible and transparent information as well as to facilitate environmentally sound consumption.

Thus, it is necessary to have clear guidelines about the communication of results. The following points are considered in the description of possible communication strategies:

- Who are the potential target groups of communication (private or institutional consumers, public, producers and distributors)? (sub-chapter 6.2)
- At which place is the information shown (on the product, the shelf, the bill, on leaflets, internet pages, etc.)? (sub-chapter 6.3)
- How do consumers see their environmental information needs? (sub-chapter 6.4)
- How can the information about the product be designed (quantitative, qualitative, highlighting best products or worst products)? How can indicator results be shown in a way that is easily understood by consumers? (sub-chapter 6.5)
- How can we differentiate between information about the production, the use of the product and end-of-life disposal? (section 6.5.1)
- What should be influenced: the buying decision, behaviour in use, or the end-of-life disposal route? (section 6.5.4)

Here we look mainly at aspects which are relevant from a scientific point of view concerning the calculation and communication of indicators. Nevertheless, further research would be necessary to fully develop a communication campaign after finalising the environmental product information itself.

6.2 Target groups and audience

The choice of the most qualified approach for providing environmental information for products depends on the target group. We consider end consumers as the main target group and develop the approach for this group. This is sometimes also termed as business-to-consumer (b2c) information. We do not further investigate the possibilities of business-to-business (b2b) communication. Different actors will have a quite different view on EPI. These views are described in the following section.

6.2.1 Consumers

Overflow of information and labels needs to be considered. Consumers want clear recommendations about the best product, but it is not immediately apparent what this really includes.

Until now, environmental product labels mainly provide guidance for consumers with a certain degree of interest in and awareness of environmental matters. The reach of such information depends on the design or size of the EPI as well as on understandability and relevance for the consumer. One can also observe that even dissuasive information such as that on cigarette packages about health effects by no means reaches all consumers nor convinces them not to buy cigarettes. Thus it is not guarantied that information alone will change the buying decisions of the consumer.

6.2.2 Producer

Producers might fear a high workload and direct competition with others. The acceptance of showing EPI also depends on how far competing products are produced by the same company or not.

6.2.3 Retailer

Retailers are often interested in marketing own brands and labels by using environmental information. They do not have so much interest in developing a common approach that cannot be used to differentiate their own products from those of other retailers. On the other hand, following a common, accepted approach may also be an advantage, as it gives more credibility to the information.

Retailers might not have a high interest on direct environmental comparisons, if products with a higher price might be environmentally less favourable compared to products with a lower price. An example would be the promotion of vegetarian food. Labels on organic products, fair trade or the Climatop label for washing powder are examples where a higher priced product is seen as environmentally favourable compared to lower priced product. This partly explains the retailers interest in promoting such labels. Hence, retailers could have an interest to promote higher priced products through environmental product information.

There are some examples where retailers have provided disadvantageous labels, e.g. the by-air label of Coop. Certain retailers are striving to improve their products and replace products with high environmental impacts with those having lower impacts. This does not necessarily involve labelling or showing the negative information on the products, yet is seen as an environmentally friendly activity that helps to improve overall environmental performance.

6.2.4 LCA community

The LCA community has an interest in data availability and incentives to provide reliable data on production patterns of consumer products. Experts in the field of LCA are used to dealing with uncertainties and figures for key indicators of environmental impacts.

6.3 Place to show information about consumer products

Information about consumer products can be brought to the consumer by different means of communication. These are described below.

6.3.1 Packaging

Already today consumers can find a huge variety of information on products. These include

Most important information

- Price
- Weight or volume
- Contents of ingredients
- Health warnings, e.g. chemical products or cigarettes
- Shelf-life
- Manufacturer
- Origin
- Environmental information (e.g. Energieettikette)

Other information

- Price per kilogram or other unit
- Code bars for price scanners
- Usage information, e.g. dosage for washing powder or heating time for convenience food
- Information about nutritional values (calories, fat, sugar, proteins, etc.)
- Information about allergenic substances
- Guideline daily amounts (GDA). Share of nutritional values compared to recommended daily intake.

- Product labels concerning specific aspects of production (e.g. organic, fair trade, regional label, etc.)
- In consultation: information about healthy products (CHOICES)[22]
- Recommended disposal routes (pictogram) or disposal systems (green dot)

Marketing information

- Picture of the product
- Pictures for marketing the product
- Name of the product
- Claims about properties e.g. taste
- Sales discounts
- Bonus programme

6.3.2 Shelf

The shelf in the supermarket may also exhibit certain items of information. These are for example

- Price per package and per unit
- Bonus programme, e.g. Superpunkte, Miles and More, Cumulus Card, etc.

6.3.3 Bill

The bill shows mainly the price, discounts and bonus programme information. There are some examples from France where the total environmental impact of the purchase is shown on the bill.

6.3.4 Catalogues

Catalogues provide detailed information about single products including the price (e.g. mail order firm, furniture catalogue, etc.). They can be directly used by the consumer for purchasing decisions e.g. with the option to fill in an order form. Catalogues can provide the information mentioned before, but also more detailed information about single products. E.g. for clothes it is mentioned for which purposes they can be used. Catalogues assist the consumer in their buying decisions especially regarding products that are not bought every day, e.g. furniture, textiles or cars. Some people might also use it if shops are not in easy reach in remote areas or due to handicaps. For some types of goods or services catalogues may even be the main option to present different alternatives (e.g. holiday journeys). In these cases, they will be the most suitable media for providing environmental information.

6.3.5 Leaflets

Additional information about labels, nutritional information, manufacturers and retailers can also be shown in printed leaflets. Leaflets do not necessarily contain information about single products and prices nor an order form. They can also go beyond the information mentioned before and provide more detailed information about certain aspects such as labels, nutritional value, usage of products, etc. Such information sources are suited to provide more details about environmental aspects of certain product categories. These media do not focus necessarily on single products, but can also provide information about one aspect, e.g. one particular environmental impact such as climate change. It can be assumed that leaflets will be mainly read by consumers who are interested in the aspects tackled; thus they may have less influence on buying decisions.

[22] Interesting discussion concerning the feasibility of a further product information and its usefulness. *http://www.nzz.ch/nachrichten/schweiz/verfuehrung_zum_gesunden_1.3787616.html*

6.3.6 Advertisements

Advertisements in printed or electronic media can as well be used for providing certain information about products. Examples are health warnings for cigarettes or fuel consumption of cars. Within the EU, it is currently discussed to require information about the energy consumption of energy using goods in each advertisement.[23]

6.3.7 Internet

Space used for information is a scarce and limited resource in printed media and on product packages. In contrast, space (memory) available for information on the internet is nearly unlimited. However, the maintenance of extensive information and keeping it up-to-date can cause major costs.

The internet can be used both for information in the form of catalogues directly linked to order forms (online shopping) as well as for supplementary information, which is normally provided in leaflets or advertisements.

6.3.8 Independent product information

Information and comparisons of products can also be found in independent media such as articles in newspapers or journals. The information is provided by public or private media companies or consumer organisations. Quite often different products are compared concerning certain criteria such as price, technical properties, quality or environmental aspects. Environmental product information might become an important part of such independent publications comparing different products. This can already be seen today e.g. on car testing including information about carbon footprints per kilometre.

6.3.9 Conclusion

The examples mentioned above show that environmental information for products is in competition with other information that attracts the interest of the consumer during the buying decision. All information has to be provided on a quite limited space available for printing on the packaging. Attention is normally directed by the producer mainly to marketing issues such as taste or function and not to neutral additional information on the product.

The price of a product as well the personal perception of the product is of major importance for most consumers' decision-making. We have the perception that, in order to come to an efficient decision, consumers tend to focus on the product information they consider most important and neglect other information. Thus it might be difficult to ensure the recognition of consumers if yet another item of information is added to the package.

In addition to the environmental information on the product packaging, the underlying life cycle assessment as well as more differentiated results could be described in a standardised report and made publicly available in an appropriate online database.

It seems to be easier to provide information in catalogues or leaflets, because here the space is not as limited as if the information is directly provided on the packaging or in the shop. Such information can be studied by the consumer at home before the buying decisions. It thus would be possible to better describe the environmental information. However, such information is mainly used for once-in-a-while decisions and not for daily goods.

[23] *www.meedia.de/nc/details-topstory/article/umweltminister-bedroht-anzeigengeschft_100024560.html*
www.horizont.net/aktuell/marketing/pages/protected/Zwangsinfos-fuers-Klima-Schwarz-Gelb-laesst-neue-EU-Werberegulierungen-passieren_88465.html

6.4 Perception of product information by consumers

How do consumers deal with the task of making an environmental judgment of a product? The public and many practitioners believe that providing people with information is sufficient to encourage environmentally friendly behaviour and that people's judgments or preferences are stable. To promote sustainable consumption, an understanding of the dynamics of environmental judgment is highly relevant.

A recent report commissioned by the FOEN investigated consumer habits and possibilities for increasing environmental sound consumption patterns (Visschers et al. 2009).

Here we summarise some further examples of research work about the perception of environmental labels or information by consumers.

6.4.1 Ways to an easily legible and comprehensible eco-labelling system – a consumer survey in France

With respect to the French laws and guidelines on environmental product declaration, a survey on the layout of product labelling was carried out by Ernst and Young consultants. The survey focuses on the importance of information given on the label and on the communication approach preferred by the French consumer (Ernst and Young 2009).

Forty percent of the consumers consider the type of value presented on the product (e.g. absolute value, relative value, grades) as the most important element for a comprehensible product information. The second most important information is a global grade for the product's environmental performance and the easily legible graphics (23% each).

Eleven percent of the consumers judge it as vital that the label ensures an independent review of the labelling process. The least important criterion was found to be the naming of the impact categories given on the label (3%).

These findings of the survey lead to the following recommendation for the communication approach of an environmental product information:

- Consumers prefer grades that express the environmental performance (grade B) within an impact category over absolute values (e.g. 15 g CO_2-eq.)
- An additional global grade is preferred, which rates the environmental performance over all impact categories and allows for a rapid judgement
- Histograms are preferred over spider scales or tables (similar to "Energieetikette")
- The label should ensure that the labelling is reviewed independently
- The impact categories should carry simplified names (climate instead of CO_2 emissions)

6.4.2 Psychological research on consumer judgements

Furthermore we evaluated an article on psychological research summarising different findings (Tanner 2008).

Research work investigated whether consumers judge the environmental quality of food products differently according to whether the products are presented separately or jointly and whether assimilation or contrast effects are more likely to occur. Contrast effects describe the change of valuation if a different set of alternatives is compared to the subject product. Assimilation effects describe the harmonisation of judgements on different products if they are presented under similar circumstances. This is often used in advertisements were positive attributes (e.g. nature, attractive persons) are linked to the perception of a product.

One study revealed contrast effects when products were judged in separate evaluations. Another study revealed assimilation effects when products were judged in one joint evaluation. However, increasing the range of the product alternatives produced a displacement of the judgments in the opposite direction, indicating contrast effects again. Comparing the environmental judgments across both studies, reversal effects in judgments and ranking of products was demonstrated. Thus, judgments of consumers also depend on the standard to which the target is compared (Tanner 2008).

In prior research, it was shown that environmental judgments are dependent on the nature of the judgment task (i.e., how consumers compare a given product with an implicit or explicit standard; Tanner & Jungbluth 2003).

There are four main conclusions that can be derived from this research. First, contrast effects are likely when consumers judge food products that are presented alone and compared to an environmental standard (Study 1). Second, assimilation effects are likely when consumers judge food products that are presented jointly (Study 2). Third, changing the range of available alternatives by enlarging the set is likely to produce displacements of environmental judgments in the opposite direction (Study 2). Fourth, the same product is judged differently and the order of the products varies depending on whether it has been judged in separate or joint evaluation mode, reflecting reversal effects. Overall, the findings emphasise that environmental judgments are highly unstable and context-dependent. Clearly, this has important practical implications.

Consumers who are motivated to make environmentally appropriate purchases will base their choice at least in part on their judgments. Therefore, consumers may sometimes purchase a product that they erroneously believe to be an environmentally friendly one.

The study authors believe that the present research contributes to understanding how and why environmental judgments are unstable and flexible, and why the strategy of providing consumers with environmentally significant information is likely to be of limited success (Tanner 2008).

One possible practical recommendation to promote sustainable consumption is to foster strategies that integrate environmentally significant information; for instance, in a single product label. It may be helpful and much easier for consumers if some kind of product labelling informs them of whether a product leads to more or less environmental harm (Tanner 2008). Such label should integrate all relevant dimensions from an environmental point of view and should give clear recommendations or at least an assessment within a comparative scale such as used for the “Energieetikette” (Tanner 2006).

To direct consumer choices in the intended direction, the EPI is only one part of many influencing factors such as

- Price of alternative, presumably better suited products
- Personal preferences of the consumer
- Other properties of the product which are considered more important
- Time constraints which prevent the customer from searching a better product
- Advertisements providing a comfortable feeling about the product

6.4.3 Recommendation

We conclude for our study that environmental product information should be as comprehensive as possible and relevant for the consumers. It should not “burden” the consumer with value judgements based on different indicator results that have to be evaluated and weighted by the consumer. It would e.g. be difficult for the consumer to handle parallel indicator results for energy use, global warming potential, land occupation and acidification which have to be weighted and interpreted individually.

6.5 Options for the design of environmental product information

Several options exist for the design of environmental product information, e.g.

- Labelling of products that fulfil certain requirements concerning environmental impacts in the life cycle
- Labelling of the best product in a predefined class of products.
- Quantitative comparisons, e.g. product A causes 10 % less impacts than product B (used e.g. for organic versus conventional food).
- Assigning products to reference classes (e.g. class A to G in the Energieetikette)
- Showing absolute values of environmental impacts per packaging size, per functional unit of consumption or per monetary value
- Comparing the environmental impact with a reference value e.g. average of product class, total consumption, recommended impacts of consumption
- Providing information about the share of the impact compared to a total (current load or target) (dimensionless)
- Comparing environmental impacts with a threshold value

The proposal for the design of environmental product information should meet following objectives:

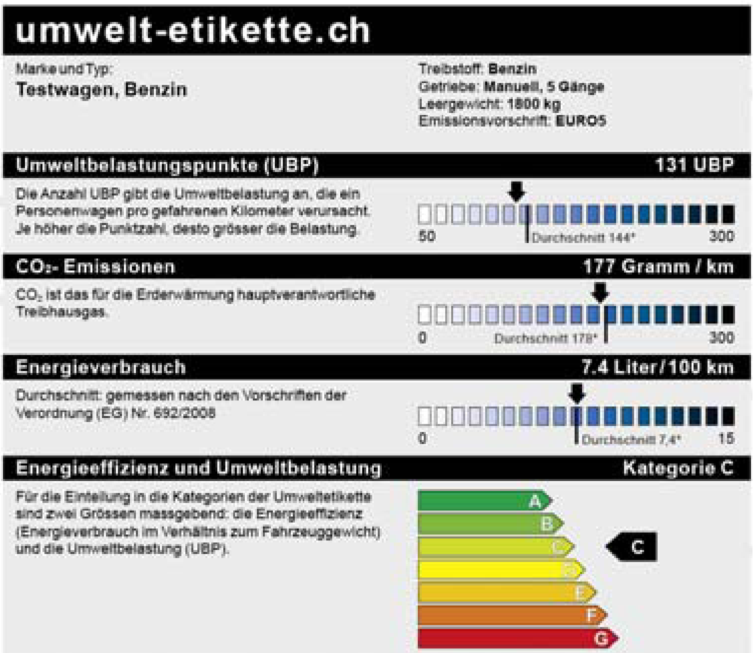
- Understandable units
- Reference value in order to judge the unit
- Comparability within suitable product categories
- Reliability and low potential for wrong conclusions

Some possible options are now explained in more detail.

6.5.1 Declaration of environmental profile

For communicating findings to private end consumers, one option is applying a combination of qualitative information and quantitative values similar to the environmental declaration (Umweltetikette) proposed for cars (see Fig 6.1).

Fig. 6.1 environmental declaration of cars in Switzerland



The qualitative information could be a classification of the product based on the quantitative values of the environmental impacts of the product compared to a reference value. Possible reference values compared to the environmental burden at the shop are:

- The daily environmental burden per capita caused by Swiss consumption in a sustainable world
- The current daily environmental burden per capita caused by Swiss consumption
- A yearly decreasing environmental burden starting with today's burden and decreasing each year in order to achieve a sustainable world e.g. in 2050.

The total environmental burden includes direct emissions in Switzerland as well as imports and exports. A simplified calculation is made in sub-chapter 5.1.

For products whose environmental impacts are strongly dependent on their use phase (or their end-of-life phase), it is recommended to declare separately the environmental impact of the use phase. This should be based on standardised assumptions on consumer behaviour.

If single-score values representing the total environmental impact of a product are considered for environmental product information, additional information e.g. on the environmental impact of the different product stages or a split of the environmental impact into different environmental categories is required if an EPI is to be arranged on a webpage similar to *www.respect-code.org*. On such a webpage, interested consumers could enter the bar code of a product in order to obtain detailed information about the underlying methodology and the environmental impacts of the specific product.

Values for the total environmental impact of a product per kg of product can be supplemented by values for the environmental impact per specific functional unit of the product type in order to enable a better comparison of different products with the same function. For food products for example, it would be useful to declare the environmental impact of a certain standard net weight (e.g. 100 g) in accordance with the information in nutritional food profiles (see Fig 6.2), whereas for many other products (e.g. toothbrushes) it does not make sense to refer to their weight.

Fig. 6.2 Food profile of Coop products

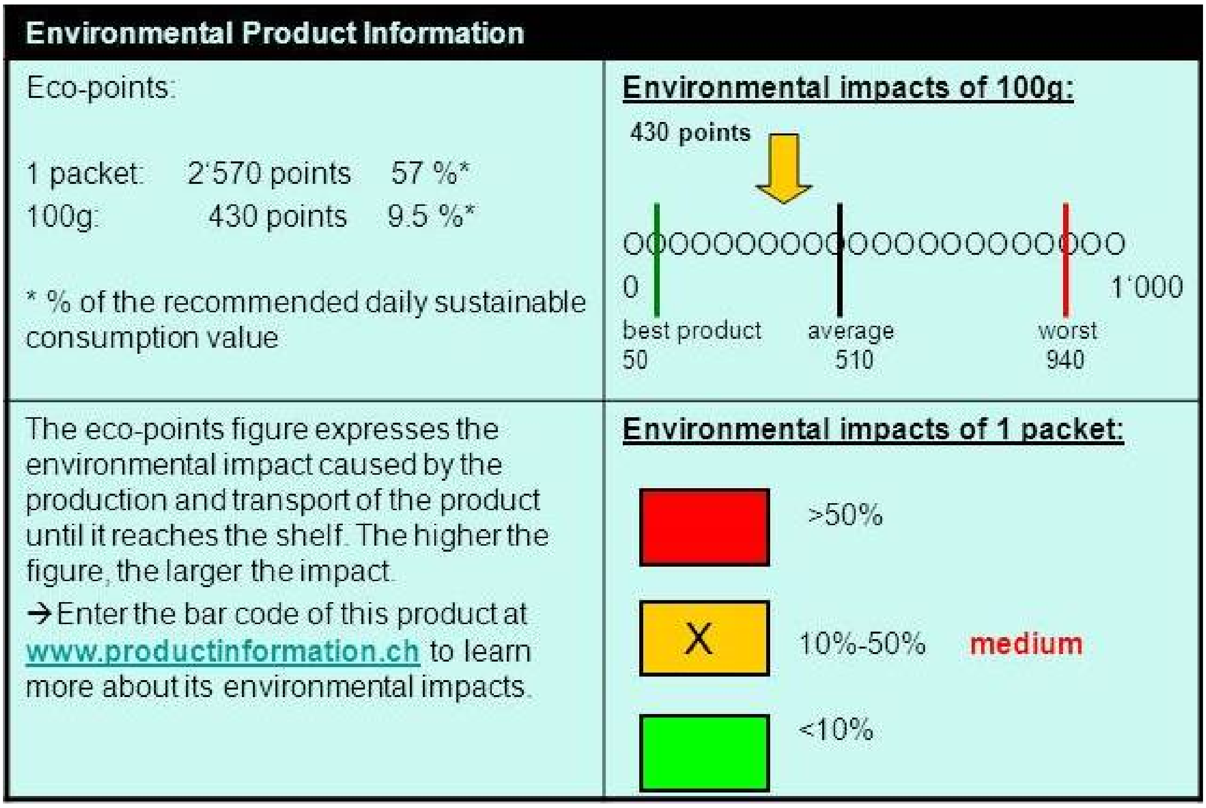
FOODPROFILE → www.coop.ch/foodprofile

Nährwerte Ø Valeurs nutritives moyennes	100g	1 Packung (250g) 1 paquet (250g)	% ETB* % RNJ*	ETB* RNJ*
Energie/énergie	640 kJ (153 kcal)	380 kcal	19%	2000 kcal
Eiweiss/protéines	8 g	20 g	40%	50 g
Kohlenhydrate/glucides	25 g	62,5 g	23%	270 g
davon Zucker/dont sucres	1,5 g	3,8 g	4%	90 g
Fett/lipides	2 g	5 g	7%	70 g
davon gesättigte Fettsäuren/ dont acides gras saturés	0,9 g	2,3 g	12%	20 g
Nahrungsfasern/ fibres alimentaires	5 g	12,5 g	50%	25 g
Natrium/sodium	0,27 g	0,68 g	28%	2,4 g
Kochsalz/sel de cuisine	0,7 g	1,8 g	30%	6 g

* Empfohlener täglicher Bedarf eines durchschnittlichen Erwachsenen. Der Nährstoffbedarf variert je nach Alter, Geschlecht, körperlicher Aktivität etc.
* Repères nutritionnels journaliers pour un adulte. Les besoins nutritionnels varient en fonction de l'âge, du sexe, de l'activité corporelle, etc.

To make the environmental impact of a product better understandable in a further step, the environmental burden of the best, average, or worst product in the same product group and with the same functional unit could be printed on the EPI for comparison. For this it would be necessary to develop detailed PCRs. A proposal for an EPI is shown in Fig 6.3.

Fig. 6.3 Proposal for environmental product information



6.5.2 Environmental Currency Unit (ECU)

For consumers it is quite difficult to understand units of environmental indicators such as eco-points. One possibility would be to normalise the critical or total burden according to the average money available for purchases by households. We assume that the average person has a budget of 34'000 CHF per year available for consumer purchases (not including state and local tax, but including rents and all other fixed costs) (BfS 2007).

The critical load according to Fig 5.1 is estimated at about 14 MM eco-points. We define the critical burden as 34'000 ECU (Environmental Currency Units or UmweltRechnungsEinheit –URE) per year and use this value to transfer the cumulative environmental impacts expressed in eco-points to ECU units. With the case studies in this report, we calculate the figures shown in Table 6.1 for consumer products from cradle to basket. As an additional example we show the impacts of the use phase of a car and of an air travel. The comparison of the calculated ECU with the product prices shows for example that the economic costs of a flight would be much lower than its ecological costs. This is indicated with a "budget indicator" describing the ratio between environmental and financial costs.

A severe disadvantage of linking ecology with the economic budget could be the perceptions of different income classes. A rich consumer is likely to take the ECU costs less serious than a poor consumer does. For a low income household environmental costs of e.g. a T-shirt, expressed in a unit similar to an economic currency could be considered high, whereas a rich person would consider the environmental impact compared to his total budget as negligible.

The definition of the critical load would need some political discussion. It might make sense to define the time frame until when the critical load should be achieved.

Tab. 6.1 Conceptual example of SECU of consumer products calculated from cradle to basket

Product	Ecological scarcity eco-points	Ecological Budget SECU	Economic Budget CHF		Budget indicator SECU/CHF
Annual budget	13'900'000	33'924	SFr.	33'924	100%
Spinach, deep frozen, 1 kg	3'000	7.32	SFr.	7.74	95%
T-Shirt, cotton	12'400	30.26	SFr.	30.00	101%
Car, VW Golf	6'370'000	15'546.61	SFr.	50'000.00	31%
Car driving, 10'000 km	2'320'000	5'662.19	SFr.	1'500.00	377%
Mineral water, 1 litre	200	0.49	SFr.	1.20	41%
Flight, New York, 12600 km	920'696	2'247.05	SFr.	485.00	463%
Electricity, 1 kWh	340	0.83	SFr.	0.15	553%

6.5.3 Environmental Time Unit (ETU)

A concept similar to ECU, which is based on economic budgets, could be based on time budgets. Time is one of the few things that everyone is experienced with and of which all people have the same annual budget, regardless of their income or any other social differences.

We normalise the environmental burden per year with the time in one year (365 days, 8760 hours, 526 thousand minutes, 32 MM seconds). This allows the consumer to easily assess the burden of a product in relation to his or her annual budget. We call the units eco-years, eco-hours, eco-minutes, etc.

Table 6.2 shows the environmental impacts of the same examples as before. A return flight to New York takes about 28 eco-days of the annual budget against real time duration of half a day. The manufacture of a T-Shirt is equivalent to about nine eco-hours. Buying a new car takes 4700 eco-hours, but these can be written off by the consumer over 8-10 years of usage. Car driving of 10’000 km costs 1'700 eco-hours, but with an average speed of 50 km/h only 200 hours of real time.

This approach could also be used if the ecological scarcity method is developed with a regional focus larger than Switzerland. The idea can also be applied for other indicators with clear defined targets, e.g. global warming potential and one tonne of CO_2-eq per capita and year. However, it cannot be used within regions which have not formulated explicit targets for the level of environmental impacts to be achieved.

Tab. Tab. 6.2 Conceptual example of SETU of consumer products calculated from cradle to basket. Preliminary results for annual budget to be revised in an ongoing project (Jungbluth et al. 2010c)

Product	Ecological scarcity eco-points	Ecological Time eco-hours	Usage time estimation hours	Budget indicator eco-hours/a	Ecological Time
Annual budget	11'954'601	8760:00:00	8760:00:00	100.00%	365d 0h 0` 0``
Spinach, deep frozen, 1 kg	3'000	2:11:54	0:30:00	0.0251%	0d 2h 11` 54``
T-Shirt, cotton	12'400	9:05:11	1600:00:00	0.1037%	0d 9h 5` 11``
Car, VW Golf	6'370'000	4667:45:33	2000:00:00	53.2849%	194d 11h 45`
Car driving, 10'000 km	2'320'000	1700:01:54	200:00:00	19.4068%	70d 20h 1` 54``
Mineral water, 1 litre	200	0:08:48	0:10:00	0.0017%	0d 0h 8` 48``
Flight, New York, 12'600 km	920'696	674:39:37	13:00:00	7.7016%	28d 2h 39` 37``
Electricity, 1 kWh	340	0:14:57	10:00:00	0.0028%	0d 0h 14` 57``

eco-hours provided in hours : minutes : seconds
Ecological time provided in days, hours, minutes, seconds

6.5.4 Information for the use phase and product disposal

The EPI developed here focuses on the production of the product. We think that the use phase and disposal route can be better influenced by clear recommendations (e.g. dosage information for washing powder or recycling information for material) instead of a quantitative figure for environmental impacts of different options.

6.5.5 Standardised design or several options for showing the EPI?

Another issue that needs to be considered is the standardisation of the design for EPI. The “Energieetikette” is one example of a clearly prediscribed design that cannot be changed for the single brand. Thus, it is easy to recognise for the consumer. On the other side there are labels, such as those for organic products, where many retailers have developed an own design like “naturaplan”, but mainly follow uniform standards such as those of Bio Suisse. This makes it more attractive for the retailer to make advertisements for these products. We would recommend prescribing one design for the EPI. Producers and retailers would then compete based on environmental impacts and not on the better design or marketing of such information.

6.5.6 Conclusions concerning design of information

We consider it necessary to conceive the environmental information in units that can be easily put into perspective by consumers. One could try to inform consumers more about the meaning and units of the ecological scarcity method, or one could convert the environmental impacts to units known by everyone. We therefore consider eco-time to be the preferable concept.

Eco-time can be calculated based on today’s average emission patterns. But this would lack a clear incentive for consumers and producers to reduce environmental impacts. Therefore clear reduction targets are necessary that have to be agreed on at national or international level.

6.6 Conclusions concerning communication strategies

Within this chapter, we analysed the possibilities for providing environmental information to consumers. We focused on products used by private end consumers. And we focused on aspects concerning buying decisions and not the use phase or disposal route.

Environmental information could be provided not only on the packaging of the product, but also on the shelf, the bill, in catalogues or leaflets. Information provided directly on the packaging would be in competition with other information that can be considered in the buying decisions. The best way of providing information depends also on the type of product and the average time taken by consumers to make their decisions. The information needs to be quite comprehensive and understandable if it shall influence the decisions.

Information provided in catalogues or leaflets can be more detailed than information printed on packaging. Thus, this form of information would be recommendable especially for products where consumers can invest some time in their decisions, e.g. buying a car or booking a holiday journey.

Ensuring that consumers will consider information for their buying decision seems to be a difficult task. Thus, any strategy would need to take possible restrictions into account. It would be necessary to inform consumers about the meaning and usefulness of such information.

The environmental information for products should be provided on an absolute scale. It would therefore be necessary to inform consumers about the meaning of the environmental indicators used. Providing information in the unit of eco-points might be difficult to understand for consumers, as they do not have any practical meaning. Therefore it might be useful to recalculate environmental impacts to a unit known and understood by everyone. We recommend using the unit "eco-time". It links annual environmental impacts to the hours of a year. It works with present and any future environmental impact targets.

7 Recommendations for EPI development

7.1 Introduction

The conclusions and recommendations summarise the main aspects of this study and provide guidance for the following goals and questions:

- Describe the full approach in short guidelines.
- Which are the priorities environmental product information? For which product groups can environmental information be provided? Which alternatives exist if the approach cannot be applied to certain product categories (section 7.2.2)?
- Which method should be used for the environmental information of consumer products, for the inventory analysis (section 7.3.3) and the impact assessment (7.3.4)? Are there any further options for simplification (section 7.3.5)?
- How could the process be organised and what would the workload be (sub-chapter 7.4)?
- How could environmental information be shown to consumers (section 7.5.1)? Could it also be used for national accounting (section 7.5.2)?
- Which other options could be identified in order to help consumers make environmentally sound buying decisions (sub-chapter 7.6)?
- Could the approach be used outside Switzerland (sub-chapter 7.7)?

7.2 Clarification of goals

Different goals lead to different approaches. Exactly defining the goal of providing environmental product information is thus a prerequisite for any further development. The main goal for the approach developed in this study would be to directly influence consumer decisions in favour of more environmentally friendly products.

Secondary goals of the present approach are:

- Introduce life cycle thinking in industry
- Improve environmental data availability for consumer products

7.2.1 Levels of decision-making

All methods considered for the development of this approach allow us to address different types of questions. Therefore we distinguish decision-making levels (DML) in the approach. It is essential to clearly define which type of comparisons or decisions should be assisted with EPI. Thus, it might be necessary to help consumers mainly to decide between two types of milk, i.e. which one is the more environmentally friendly, or to judge if it is better to make a vegetarian meal compared to a meal with meat.

The level of decision-making determines the level of detail that is necessary to collect data for a specific product. The lower the DML the higher is the workload for investigating necessary data for single products. However, this workload also depends on the number of alternatives or the knowledge already available.

It is not possible to address all types of possible decisions and questions with one kind of information. EPI should start with generic values assisting the higher level of decision-making, e.g. meat vs. vegetables or car vs. train. Hence, it is sufficient to calculate one average environmental impact per kg of meat versus the environmental impact per kg of vegetables. By gaining more and more experience, it would be possible to refine the approach by differentiating information within need fields. Further on, one could differentiate within product groups or individual products. Such information would help consumers to better understand the relevance of buying decision and focus attention on those decisions which are most important.

As a conclusion, it is necessary to begin by defining the DML to be adressed with EPI. This determines the workload, the choice of the functional unit and the limits of the system.

7.2.2 Product groups and priorities

The following aspects should be considered with first priority for the choice of product groups to be investigated:

- Importance with respect to overall environmental impacts (e.g. mobility, housing, food)
- Clear alternatives and limited number of product variants (e.g. electricity)
- Clear differences concerning the environmental impacts of products within the category (e.g. meat versus vegetables)
- Trendsetting markets in development, e.g. new electronic products (iPhone, iPad), where consumers need better guidance for purchasing decisions
- Products with good availability of information and data to model the life cycle inventory and which are easy to start with (e.g. electricity)
- Products with poor availability of information and where thus new insights can be expected (e.g. electronics, textiles, body care)

Most labelling or EPI now focus on daily products such as food products. However, from an environmental point of view it might make more sense to focus on environmentally important consumer decisions and not on products which would only lead to a small change in the total environmental impacts caused.

A possible criterion for the choice of product groups might be the amount of investment per year. Large investments will in principle cause higher environmental impacts due to one decision than daily goods. It might make more sense to give priority to these large investments (e.g. more than 500 CHF) before investigating a range of different daily products.

In an overall assessment, food and drinks, private transportation, and housing are often mentioned as the most important fields of private consumption from an environmental point of view. However, there are important differences with respect to consumer decisions. Buying food and drinks involves frequent and daily consumer decisions on several aspects. Even if there may be large differences between individual food items, general differences between purchasing patterns are not as important. All people need a certain amount of food that cannot be reduced or increased considerably. Thus, the main difference is primarily due to general dietary choices (vegetarian versus meat) and thus a higher DML should be considered.

For the two other fields, differences between single consumers tend to be much higher. There are consumers with quite low impacts e.g. those not driving a car and not travelling (flying) a lot, and on the other side consumers that cause several times higher impacts. The same holds true for differences concerning the space and energy needed for housing. Thus these two fields would be much more important regarding environmental information than the food sector.

First, one could start with the investigation of the average environmental impact of the following products (higher DML):

- Different means of transportation (trains, bus, airplane, etc.). Tools for calculating the impacts are available and have to be harmonised with the goals of EPI.
- Housing and flats with simplified assumptions e.g. per m^2 of typical building types.
- Different heating systems operated in and insulation applied on buildings
- Different electricity products
- Holidays and tourism, leisure activities (skiing, skating, etc.)
- Electronics and communication technologies
- White goods (mainly relevant because of their use phase)
- Rough information on food product groups (average values for meat, vegetables grown outdoors, greenhouse vegetables, deep-frozen convenience food, air-transported food, beer, wine, mineral water, etc.)

- Textiles (average figure for typical products e.g. Jeans)
- Furniture

In a second step the differentiation could be detailed in order to address lower DML: Some examples are provided below:

- Vegetables: differentiate for different types of vegetables (carrots, salad, tomatoes)
- Cars: differentiate concerning the environmental impacts over the full life cycle of different car models
- Leisure activities: differentiate for activities using a motor-driven vehicle or other means of transportation, activities indoors and activities done only using human power or renewable energy (wind, water, etc.).

In a third step a further differentiation might be introduced, e.g.

- Vegetables: different types of vegetable origins (spinach, broccoli or cauliflower from different countries) or different types of production (organic, conventional)
- Leisure activities: Investigate average data for each type of activity, e.g. skiing, go-carts, cinema, theatre, museum

Only in the last step, there could be a differentiation for each single product in the shop.

7.3 Methodological recommendations

7.3.1 Basic methodology for calculating and assessing environmental impacts

In order to choose the appropriate assessment method for a given problem or question, it is necessary to know the main attributes of each method and the questions to be answered. We evaluated different methods for calculating and assessing the environmental impacts of products. For a comparison, one has to distinguish between methods that are mainly defined by the environmental indicator and methods which are defined by the way the process chain analysis is conducted. The later can be used to calculate different types of environmental indicators.

According to the criteria used in this feasibility study, the methods that are defined by a single indicator, such as carbon footprinting, do not fulfil the criterion of being meaningful in terms of the range of environmental impacts covered, as they only focus on single issues. Input-Output Analysis and Hybrid Analysis are difficult to apply in Switzerland due to the lack of the necessary background data. Material Flux Analysis is usually not appropriate to investigate and compare individual products and services. Thus we consider the LCA method as most appropriate to be used in an environmental product information for consumer products.

7.3.2 System boundaries

At the basket versus full life cycle

We generally recommend assessing environmental impacts for products from cradle to shop. The full life cycle impacts of a consumer activity such as washing or driving a car can than be analysed by consumer organisations such as Kassensturz or topten.ch as soon as information for all relevant products used by the consumer to fulfil a specific need are available.

Deviating from this principle, direct emissions in the use phase must be considered for such products that are combusted or used up. This is mainly important for fuels, solvents, detergents and pharmaceutical products that are emitted into air or water.

For all energy using products with a plug or a tank, information for the full life cycle should be shown additionally to the information about the product at the shop. It is assumed that in these cases the use phase in most cases is important with regard to environmental impacts and that the type of product can have a considerable influence on this use phase. For example, for a car, the environmental information stating the total impacts of its production could be supplemented with additional information showing the impacts of driving one kilometre with the car. This additional information would include the production of the fuel and the emissions due to burning it as well as the production and disposal of the car. Viewed precisely, sometimes it is not the product with the plug (e.g. bedside lamp), but the light bulb used with the lamp that is relevant for the energy use. The exact evaluations have to be made in the development of PCR for specific product groups.

We think that it will not be feasible to consider the full life cycle for all products where the use or disposal stages might have some importance. For single products this may be considered in the same way as for energy using products after developing full PCRs and defining a functional unit. Thus one has to take care not to differentiate products with EPI where the use or disposal stage might have an important impact for a direct comparison.

The restriction of EPI to environmental impacts caused from cradle to shop avoids the double counting of environmental impacts that would occur if one tries to model the full life cycle. Thus the information can also be used in order to calculate the total impacts of personal consumption, even on a national level.

Functional unit

With the approach “at the basket”, it is possible to provide information directly for the amount of product purchased (e.g. one car, one train ticket, one yoghurt). Producers might agree within product category rules (PCR) on a functional unit for which information is shown additionally in case of energy using products. This functional unit allows comparison within a predefined group of products e.g. cars. It describes the function provided by the product e.g. transporting one person over one kilometre.

This might be also used for other products such as washing powder, where the “amount used for an average wash” would be an appropriate functional unit. Therefore different producers have to agree on PCR defining the necessary scenarios.

Product Category Rules (PCR)

The full goal and scope for labelling of certain product groups in the framework of an EPD is defined in “product category rules” (PCR). Product category rules are a form of guidance and rules for the collection of data and other information, for the selection of the environmental impact category indicators and for how this information should be presented. Some aspects covered in PCR are for example:

- Functional unit
- System boundaries of the modelling
- Background data used
- Allocation rules
- Cut-off rules and simplification possibilities
- Emission modelling
- Impact indicators reported

We recommend establishing PCRs mainly for integrating the use or end-of-life phase for specific product groups. This would be an add-on to the general concept of EPI. For example, PCRs are necessary for all products with a plug or a tank.

The PCR process should be carried out in an open process in which various stakeholders have the opportunity to comment. This is important to make the PCR documents of as high quality as possible. A prerequisite for the development is normally a detailed LCA that also investigates some scenarios for the specific product group. This helps to understand the influencing factors. When all relevant comments are incorporated into the PCR it is approved and established by a technical committee. A further possibility, so far not used in EPDs or PCR, might be to agree on simplified key parameter models during this process.

Simplified PCRs for single products might also be developed within pilot LCA studies in order to establish generic values of environmental impacts for a certain product group. These pilot LCA will help to identify hot spots in the life cycle and establish specific rules e.g. on allocation in a certain process step. Thus e.g. a pilot LCA for milk products can establish the basic rule for allocating environmental impacts of milk throughput to a dairy. These rules need to be adhered to in all subsequent studies on dairy products.

7.3.3 Life cycle inventory analysis

Within the life cycle inventory analysis, environmental data are investigated throughout the life cycle. We summarise the main recommendations concerning the LCI for elaborating environmental information for products.

- Use ecoinvent data or data of similar quality and characteristics as a background database.
- All other data need to be investigated according to the methodology of the ecoinvent project (Frischknecht et al. 2007b). Use the methodology applied in ecoinvent v2.0 for defining the allocation in case of multi-output processes. Use attributional modelling in the LCI.
- Do not allow inclusion of carbon offsetting as part of the LCI.
- Model real product inputs according to economic relationships.
- Foreground and background system need to be defined in PCR
- Apply average data of the most recent year or in case of annual variations for the last five-year period.

So far the ecoinvent database provides mainly information for intermediate products such as electricity or steel which are used in production processes by companies. There is only little information on consumer products and their typical production processes. Thus, it is recommended to place a stronger focus on such products and production processes in the further development of this public database if one wants to assist the development of EPI.

7.3.4 Life cycle impact assessment and indicators

Several methods for the characterisation of environmental impacts and the calculation of single-score indicators have been analysed and compared in this study. It has to be noted that LCIA methods cannot really be compared. Each of the methods has different features and underlying assumptions. Thus, they cannot be ranked absolutely, but only in terms of the goals and priorities set by the decision-maker.

We recommend using the ecological scarcity 2006 method for environmental product information. The method is specifically designed to represent the assessment of environmental problems from the Swiss perspective. It covers many environmental problems and the method can be adapted to cover further environmental topics (e.g. more regionalised assessment of water use, noise, other environmental issues which are decided on the political agenda). The method is suitable for all types of products and can be used on a regional or national level.

We see some improvement options – for instance, regarding the assessment of pesticides or regarding the inclusion of effects on biodiversity due to land-transformation, in particular due to clear cutting of primary forests.

Nevertheless, other LCIA methods might also be used. ReCiPe is considered as the second best option, but so far, there is not much experience with this method. The evaluation of nuclear energy might be seen as a shortcoming because relevant aspects of final disposal of nuclear wastes are not considered within ReCiPe. The weighting in ReCiPe leads in many cases to similar results as in a carbon footprint analysis.

Impact 2002+ and Eco-indicator 99 (H,A) can be considered as somewhat obsolete because their basic models have been revised within the ReCiPe method. Impact 2002+ does not provide factors for the weighting step. Thus it cannot be used in environmental product information as long as there is no commonly agreed procedure for weighting.

7.3.5 Further simplifications

The present recommendations seek to simplify the approach as far as possible without losing sight of the goal of providing useful EPI for the consumer. It does not seem to be possible to further simplify the approach. On the other side, one should not start with a too complicated or detailed approach at the beginning, but should rather gather experience step by step.

7.4 Organisational and legal recommendations

There should be a clear scheme for the responsibilities of providing environmental product information. For the following responsibilities, actors need to be distinguished:

- Who wants or needs to show environmental information for his/her products?
- Who provides life cycle inventory data for the different process stages?
- Who does the necessary calculations of key environmental figures in an LCA?
- Who develops the methodology for investigating the environmental impacts?
- Who reviews and controls the process?
- Who pays for data investigation, impact assessment and review?

It appears necessary to have at least two different independent organisations for these aspects:

1 One organisation developing the methodology as well as reviewing and controlling the process. It might be better if this organisation is not financed directly by the producer, but by public funds or producer associations. This organisation (or a third one) might also establish and maintain a common database with LCI background data. Background data and data of common interest should be stored in one central database preferably building on the ecoinvent database.

2 One organisation that does the calculations (this can be the producer or e.g. a consultant paid by the producer) and provides the information. This organisation should be fully independent from the company which controls the calculation.

A good environmental product information should include a broad discussion of the methodology with different stakeholders and a critical review of the calculations done. The process should be transparent and reproducible. There should be an independent body to deal with conflicts between different producers and diverging interests.

7.4.1 Workload

Another issue is the workload for providing EPI for a range of different products. The workload will depend very much on the type of products investigated, the availability of necessary background data in public LCI databases, the DML addressed, the environmental indicator used and the contribution provided by producers. Thus, at the moment it is not possible to absolutely quantify the total workload – neither per product nor for the whole system.

7.5 Communication-related recommendations

7.5.1 Communication to consumers

Communication should give clear recommendations to the consumer, should attract the consumer’s attention and should be easily understandable. Therefore, it may be necessary to develop a communication approach once the EPI approach has been clarified.

Environmental information can be provided not only on the packaging of the product, but also on the shelf, the bill, in catalogues or leaflets. Information provided directly on the packaging would be in competition to other information that can be considered in the buying decisions. The best way of providing information depends also on the type of product and the usual time taken by consumers to make their decisions. The information should be comprehensive and understandable if it is to influence the decisions.

Information provided in catalogues or leaflets can be more detailed than information printed on packaging. Thus this form of information would be recommendable especially for products where consumers can invest some time in their decisions, e.g. buying a car or booking a holiday journey.

Ensuring that consumers will consider information for their buying decisions seems to be a difficult task. Thus any strategy would need to take account of possible restrictions. It would be necessary to inform consumers about the meaning and usefulness of such information. So far, no systematic research has been conducted on how a specific type of environmental product information could influence consumer behaviour. Before developing an approach without this knowledge, it might be advisable to better understand the influence of EPI on consumer decisions.

The environmental information for products should be provided on an absolute scale. Therefore it would be necessary to inform consumers about the meaning of the environmental indicators used. Providing information in the unit of eco-points might be difficult to understand for consumers, as they do not have any practical meaning. Therefore, it would be useful to recalculate environmental impacts to a unit known and understood by everyone. We recommend eco-time. For this it would be necessary to agree on average levels of environmental impacts as a target per year.

7.5.2 Using EPI for personal balances or national accounts

The approach presented here allows in principle to use EPI to also calculate the total personal burden of a consumer or the total impacts of consumption in Switzerland. In order to avoid the double counting of environmental impacts it is necessary to restrict the modelling to the life cycle from cradle to shop. This would allow consumers to see the relevance of the specific products for their buying decisions and to sum up the environmental impacts e.g. for one year or for personal activities such as washing clothes.

If the information is available for all products sold this would basically also allow the calculation of average or total environmental impacts of consumption including the impacts caused by imported products.

7.6 Environmental product information as a policy option

Environmental product information is only one option to promote the goals of sustainable development. The feasibility study has shown that there would be methodological challenges if several types of consumer products have to display relevant and meaningful environmental information. Here we briefly discuss some alternatives to environmental product information.

7.6.1 Financial incentives: subsidies or tax reduction

Subsidies or tax reductions designed to steer demand towards more or less environmentally friendly products appear to allow a more direct influence on consumer decisions. LCA studies can help to develop the necessary guidelines for such financial incentives, as the example of biofuel tax exemption shows.

7.6.2 Regulations on advertising

Environmental arguments are gaining an ever higher profile in advertising. From a comprehensive point of view there is a risk of such claims becoming misleading. Rules governing green advertising could therefore become necessary. In general, environmental claims should be based on full life cycle thinking considering all relevant environmental impacts.

7.6.3 Regulations on production processes

One way of influencing the environmental impacts of consumption patterns is to establish clear regulations, e.g. on the emissions and energy uses for specific production processes, which are known to have a large influence on environmental impacts. But regulations are only feasible within national boundaries. Thus this does not influence the production of the large share of imported products or materials.

7.6.4 Mandatory EPD instead of EPI

An alternative to environmental product information would be a focus on EPD. This would give an incentive to producers to learn and improve their production chains. The approach should be developed in a transparent way that also ensures increased availability of relevant environmental information on production patterns as a support for reliable LCA studies. Such an approach would be more focused on comparable products and thus would not allow for overall comparability.

7.6.5 Awareness-raising with leaflets and brochures

LCA case studies can help to illustrate environmental aspects of specific products or purchasing decisions. Such studies can investigate the influencing factors in much more detail than an EPI. Information and proposals for environmentally friendly behaviour can be provided e.g. in the form of leaflets or in the Internet. Nevertheless, the influence on consumer decisions could be limited if the information is only taken into account by a small fraction of people.

7.6.6 Generic web calculators for environmental impacts of products

Web calculators exist for certain product groups that help consumers to compare different products in one product group, such as electricity, transports or vegetables. Some links to examples can be found on *http://www.esu-services.ch/ourservices/tools/*. An option would be to systematically support such work and to provide links to several similar webtools for consumers on one central webpage. They should allow the calculation or comparison for specific types of products. If possible there should be guidelines e.g. on the indicator calculated that would also allow some overall comparability. However, the overall influence might be limited due to small number of consumers using such tools.

7.6.7 Wiki database for EPI of consumer products

An alternative to providing environmental information in terms of a web calculator would be a Wiki knowledge database where consumers can find environmental information for all types of product groups. It would be necessary to agree on some general guidelines as to which information should be included for a new product on such a page. LCA practitioners could provide results of their case studies for such a database. The description should help consumers to consider the most relevant aspects while buying products from a range of product groups. Under the heading "cars", for instance, one would find information that fuel consumption is most important while under a heading "ready-made Lasagne" there are recommendations to buy chilled ones and to prepare them in the microwave.[24] The idea could be extended by a question and answer page that helps to identify fields of interest where consumers would like to have more information.

7.6.8 Voluntary goals aimed at by retailers

Retailers of products can have some influence on the buying decisions of consumers. They have the choice to promote environmentally friendly products and to make more problematic ones less attractive e.g. by higher prices. Therefore, retailers could agree on voluntary goals for the reduction of environmental impacts.

[24] Initial experiences are frustrating. Often work is deleted or changed by other users (see discussions on *http://de.wikipedia.org/wiki/Diskussion:Schokolade#Umweltaspekte* or *http://de.wikipedia.org/wiki/Diskussion:Lasagne*. Thus this seems only feasible if there is clear control that the work is not removed or changed in a wrong way.

7.7 International collaboration and acceptance

7.7.1 Within Switzerland

LCA in general is a tool widely accepted by environmental experts in Switzerland. Most of these experts also know environmental indicators such as eco-points or the Eco-indicator 99 method.

Life cycle thinking is considered by consumers. However, for them the German word “Ökobilanz” often stands for a more unspecified synonym of "environmentally friendly" and less for a well-defined method. So far, results of life cycle based approaches are communicated with quite different indicators, such as Ecological Footprint, Oil-equivalents, Energy consumption and Carbon Footprint. Comprehensive indicators such as Ecological Scarcity or Eco-indicator are not so well known to consumers. Thus it will be necessary to develop new approaches for the provision of comprehensive environmental information in a simplified way to consumers.

7.7.2 International

So far, we see many different approaches for EPI in different countries. It could be difficult to harmonise these approaches, also because of the diverse stakeholders involved. A further difference is the choice of environmental indicators that also depends on national preferences and assumptions.

The international acceptance of LCA and LCIA methods varies from country to country. In many countries, there is a general acceptance of life cycle based approaches. But in some countries (such as Austria, USA) different methodologies such as material flow accounting or Input-Output Analysis might be more popular.

The acceptance for different indicators varies considerably between different countries and different scientific communities. Adapting an LCIA method to other countries is a political issue with potentially different points of views by decision-makers in different countries.

One-score methods are not well accepted in some countries such as Germany while they are more popular in others like the Netherlands. Preferences for such methodologies varies also regionally with different approaches followed for instance in Nordic countries, the USA, the Netherlands or Switzerland.

The carbon footprint indicator applied to consumer products is currently quite popular. Water footprint is gaining rising attention. Energy consumption is mainly considered in the building sector and the interest in ecological footprints is assumed to remain stable.

Within the PCR, the geographical scope is an important issue. Thus e.g. standard figures of electricity use in the use phase are dependent on the geographical scope. For an EPI elaborated only for Switzerland one would apply the Swiss electricity mix. If the scope is Europe, the European electricity mix would be more appropriate. Depending on the country this would cause quite high variability because of important differences in the electricity production mixes. Hence, life cycle inventory modelling is also an important issue beside the choice of the LCIA method when it comes to international co-operation.

Due to different perceptions on weighting methods, but also due to different system boundaries for calculating EPI, it would not be possible to directly use the EPI investigated in one country for the same product when it is imported to another country. But the underlying life cycle inventories can at least provide a good basis for recalculating the EPI in other countries with other methodological choices.

7.8 Conclusions

Within this report, we investigated the feasibility of developing environmental product information. The focus of research was Switzerland, but we also considered ongoing developments in several other countries.

An EPI may help consumers consider the environmental impacts of products in their buying decisions. Many methodological restrictions would have to be considered while developing a comprehensive approach. The approach should be simplified, as all possible goals cannot be met at the very beginning.

We consider the method of life cycle assessment, the ecoinvent life cycle inventory database and the ecoinvent methodology developed for the investigation of life cycle inventory data as a good starting point for EPI.

We recommend choosing a comprehensive environmental indicator that already considers several relevant environmental aspects (emissions and resource uses) and which can be further developed with increasing scientific knowledge. This helps to avoid burden shifting and reducing one environmental impact at the expense of others. Therefore we would propose to use the Swiss ecological scarcity method for calculating an indicator.

We recommend showing EPI for the product that is provided to the consumer. This includes all environmental impacts from cradle to the shop (and direct emissions from using the product). Environmental impacts from use and disposal should not be included in the EPI of this product, but in the EPI of the disposal process or the additional products necessary for the activity within this product is used.

In all cases where products have a plug or tank (meaning they are directly consuming energy), this should be supplemented with information on the full life cycle and for a predefined functional unit.

Clear procedures and guidelines would be necessary as a first step when developing such an approach. They should be based on the approach developed in this report. The development process should be led by a national authority.

In a second step, pilot LCA studies should be carried out for selected types of consumer products. The generic data should be published and collected in one central database. As long as more specific information is not available these generic results should be used for the EPI. The pilot LCA studies should also identify hot-spots in the life cycle and develop product specific rules that have to be followed by later LCA studies for products by specific producers. The pilot LCA and investigated data would need to be peer-reviewed independently.

In a third step, case specific LCA could be calculated following the overall generic guidelines and the specific recommendations of the pilot LCA.

Several similar initiatives with similar goals are ongoing in different countries. Most of these initiatives focus on the carbon footprint. Various standardisation organisations are seeking to harmonise these developments with regard to the carbon footprint of products.

After all these thoughts and prerequisites, the question is now what is good environmental product information?

In short, a good statement should be:

- Truthful, accurate and able to be substantiated
- Provided by an organisation independent from the producer and in a clearly defined procedure
- Relevant
- Clear about the environmental issue the claim refers to
- Easily understandable for the target group (i.e. consumers)
- Explicit about the meaning of any indicator

The discussion in this report of several methodological and conceptual issues has revealed that it would be impossible to develop an approach that can fulfil all goals from the very outset. The following Table 7.1 summarises the main conflicts in the development of EPI.

The left column describes the criteria that should be fulfilled by an environmental product information according to the goals set at the beginning. Thus the approach should allow good guidance for sustainable consumption The different columns stand for certain methodological choices that have to be made while developing the approach (e.g. system boundary set as cradle to shop). Red fields (-) highlight conflicts between a criterion and a methodological choice.

One choice is for example the system boundary for the information "at shop" or "full life cycle". The first allows a summation of several purchases to a total figure, while the second allows a fair comparison of individual products with a given function.

Tab. 7.1 Overview of conflicting decisions to be made in the development of environmental product information. Recommended choices marked in blue.

	Goal and Scope										LCI		LCIA								Priorities					Communication		
Criterion demanded for good EPI / Choices to be made	DML 1	DML 2	DML 3	DML 4	DML 5	DML 6	DML 7	DML 8	DML 9	Develop PCR	at shop	full life cycle	Impacts per unit	Impacts per function	Quantitative results	Qualitative results	carbon footprint	ecological footprint	ecological scarcity 2006	ReCiPe	Food	Textiles	Electricity	Housing	Mobility	Indicator result	Ecological currency	Ecological time
Allows a fair comparison of single products	.	.	+	+	+	+	.	-	-	+	-	+	-	+	+	-	.	.	+	+	-	-	+	.	+	.	.	.
Allows a good guidance for sustainable consumption	-	-	-	.	.	+	+	+	+	.	+	+	+	-	.	+	+	+	+	-	.	.	+	+	+	.	.	+
Includes all relevant aspects in the full life cycle	-	-	+	+	+	.	-	-	-	+	-	+	-	+	+	.	+	+	+	+	.	.	+	+	+	.	.	.
Low uncertainties of judgements	+	+	.	.	.	.	+	+	+	+	+	-	+	-	-	-	+	-	+	+	-	-	+	-	+	-	-	+
Inclusion of several environmental impacts	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	-	.	+	+	.	.	.	.	.	+	+	+
Approach is transparent for consumer	.	.	.	.	+	+	+	+	+	.	+	-	+	-	+	-	+	-	+	+	.	.	.	.	.	.	.	+
Low workload	-	-	-	-	-	.	.	+	+	+	+	.	+	.	-	+	+	+	-	-	-	-	+	-	+	.	.	.
Add up of impacts is possible (life cycle, household, national)	-	-	+	+	+	+	+	+	+	-	+	-	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+
One approach is possible for all products	-	-	-	-	-	-	+	+	+	-	+	-	+	-	+	-	+	+	.	.	-	-	+	.	.	-	+	+
Worldwide accepted as a method	-	-	.	+	+	.	.	.	.	.	.	.	+	+	.	.	+	+	-	-	.	.	.	.	.	+	-	-
Information on traded products is valid	.	.	+	+	+	-	-	-	-	.	+	-	+	-	+	.	+	+	-	+	.	.	.	.	.	+	-	-
Communication is understandable	-	-	+	+	+	+	+	+	+	+	+	-	+	+	.	+	+	+	+	.	.	.	.	.	.	-	.	+
Value judgements are separated	.	.	.	.	.	.	.	.	.	+	+	.	+	-	+	.	-	-	+	-	.	.	.	.	.	.	-	-

Criterion can be fulfilled	+
Criterion difficult to be fulfilled	-
Neutral concerning criterion or unsure	.

7.9 Outlook and research questions

This feasibility study revealed several issues that need more investigation and development in the future. We see for example the following.

So far the LCI database ecoinvent focused on the needs of industry and product developers. There is only very little information on consumer products. Thus, future research projects could investigate complex but typical consumer products and provide the necessary LCI inventory in such a way that it can be used for similar case studies. Some examples where only little knowledge is available are e.g. textiles (high tech clothes, fashion), electronics (mobile communication, entertainment, cameras), food (processed or pre-cooked food).

In some cases, it is difficult to find and process Swiss statistical data on the use of products that are relevant for LCA case studies. A database would be needed, for example, on total pesticide use detailed for each type of product and typical applications. Another important issue would be one regularly updated database containing information about all major domestic emissions and resource uses. So far these data have to be collected from different statistics, partly with different system boundaries (e.g. energy statistics, greenhouse gas statistics, area statistics, etc.).

The ecological scarcity method should be further developed (e.g. foreign land transformation, pesticides). Furthermore, overall environmental goals (including product imports) should be discussed with stakeholders and be fixed in time-bound steps. E.g. emission reductions until 2020, 2030, etc.

Authorities could support initiatives for international agreement on single-score LCIA methods and weighting. Therefore collaboration with single countries or interested institutions seems to be a promising way in order to establish a better international acceptance in the first step. After that, a joint effort of those member countries to implement a European version could be envisaged. It would be valuable to already have a group of countries convinced by such an approach that would have enough interest to bring the discussion forward.

A further focus might be to investigate consumer acceptance and understanding of initial ideas for the design of EPI.

8 LCA methodology

8.1 Allocation

8.1.1 Context-specific allocation criteria

The problem of allocation has first been dealt with in economics. Here costs of the production process have to be allocated to the different valuable products. J.S. Mill is often mentioned as one of the first economists who raised the question of an adequate procedure to allocate (private) costs to two jointly produced goods (Mill 1848). Criteria used today for the allocation of costs are for instance given in Horngren (1991). They differentiate between the following criteria:

a) cause and effect,
b) benefits received,
c) fairness or equity, and
d) ability to bear.

Ad a) The criterion "cause and effect" relies on physical, chemical or biological causation. It may be applied for the analysis of combined production where the output of co-products can be varied independently such as an oil refinery producing oil products (light fuel oil, gasoline, bitumen, et cetera). This criterion corresponds to the second step of the ISO 14044 procedure and is not applicable to joint production processes.

Ad b) The criterion of "benefits received" is used to allocate common costs according to the individual profits achieved by spending these common costs. The costs of common marketing activities, for example, may be allocated to the respective goods according to their individual increase in turnover due to these common activities. The criterion may be applied in cases where no market determines the price (value) of products (goods and services).

Ad c) A fair allocation of common costs is required when several decision-makers are involved in a joint production process. It implies that there is a problem of decision-making which includes negotiations in view of a commonly accepted and supported solution. This may be necessary for investments in a dam, for instance, that is used for electricity production, flood protection, drinking water supply and irrigation, and where several decision-makers and profiteers are concerned. In life cycle assessment such a situation may occur in voluntary coalitions, e.g., in the waste treatment sector. Waste "producers" may look for companies being interested in using the waste as a secondary raw material. The criterion "fairness or equity" is not provided by the ISO procedure.

Ad d) The criterion "ability to bear" allocates costs according to the co-product's capacity to bear production costs. The gross sales value and the estimated net realisable value method are representatives of an operationalised concept relying on this criterion. They consider the competitiveness of jointly produced products and result in a price structure that is optimal for the company's profit maximisation.

This short overview shows that depending on positions and situations one particular approach seems more appropriate than the other.

8.1.2 System expansion with the avoided burden approach

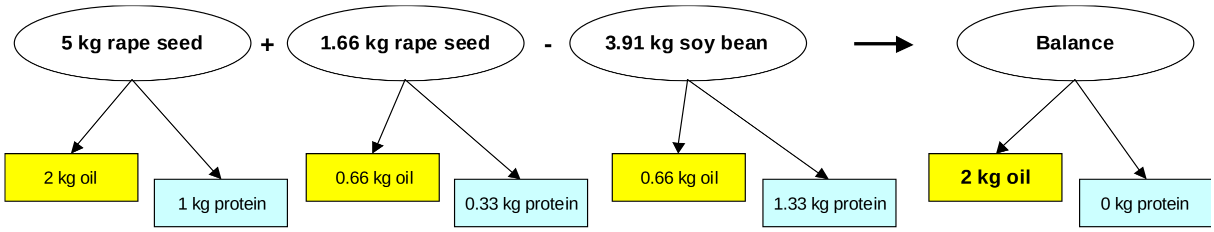
The following description of the procedure of system expansion with the avoided burden approach (here in a consequential LCA) is based on a case study for rape seed methyl ester (Calzoni et al. 2000). It is assumed that extracted rape seed meal is used as protein component in livestock feed and substitutes soy meal. The system expansion is based on the preconditions that:

- soy meal is the marginal protein fodder and rape seed oil is the marginal edible oil on the market;

- rape seed contains 40% oil and 20% raw protein in the dry matter and that soy bean contains 17% oil and 34% raw protein in the dry matter, and
- the raw protein and the oil in both rape seed and soy bean are substitutable in their marginal application.

Per 5 kg rape seed produced an additional production of 1.66 kg rape seed is added. Then a system expansion with 3.91 kg soy bean is made (see Fig 8.1). The LCA finally shows the net environmental impacts of the supply of 2 kg of rape seed oil.

Fig. 8.1 Example for system expansion with the avoided burden approach for rape seed with the purpose of avoiding allocation regarding soy bean oil and protein (Calzoni et al. 2000)



8.1.3 System expansion with the basket of benefits approach

The basic idea of the system expansion with a basket of benefits for the functional unit is quite similar to the example described before (Fig 8.1). In this case the comparison is made between a system, which delivers several benefits with one multi-output process, and a system, which delivers these benefits with different separate production processes. The results show the environmental impacts relative to the whole expanded product system and not relative to the individual products.

Applied on the example in Fig 8.1, one would define the functional unit of rape seed production as “2 kg oil and 1 kg protein”. Such a system is then compared to an alternative system which produces the same amount of oil and protein in a different way (e.g. 2 kg oil from crude oil and 1 kg protein from biomass).

8.1.4 Allocation by partitioning of inputs and outputs

The procedure of allocation by partitioning inputs and outputs is explained in more detail with an example from the ecoinvent database. According to ISO 14044, "the sum of the allocated inputs and outputs of a unit process shall equal the unallocated inputs and outputs of the unit process" (International Organization for Standardization (ISO) 2006b:4.3.4.1). This is also known as the 100% rule.

The allocation procedures shall be uniformly applied to similar inputs and outputs of the systems under consideration (International Organization for Standardization (ISO) 2006b). This is especially important if a product is an output of one process and an input of another process. Residues without value that are used by other processes have to be treated in a consistent way in processes delivering them on one hand and in processes that make use of them on the other.

Each multi-output process needs information on the allocation factors for all inputs and outputs. Each pollutant, each working material or raw material input may have its individual allocation factor, if adequate or necessary. Allocation factors need not to be limited between 0 and 100%. They may well be negative and above 100%. However, the sum of the set of allocation factors of one particular input or output needs to add up to exactly 100%.

The following relationships are frequently applied in LCA case studies (all to be classified as "other relationships"):

- Energy content
- Exergy content
- Mass
- Content of chemical elements or substances in inputs and outputs (e.g. carbon, chlorine, etc.)
- Market value or price

Table 8.1 shows an excerpt of the inputs and outputs of the wheat production process and the allocation factors as modelled in the ecoinvent database. First some examples of inputs from technosphere and elementary flows are shown. The column Z "wheat IP", gives the amounts used or emitted per hectare. In this example 67 kg of nitrogen in ammonium nitrate are required and 3.9 grams of cadmium are emitted to agricultural soil per hectare. The allocation factors applied on the two products "wheat grain" and "wheat straw" shown in the columns AG and AH define the share of the total amounts which are allocated to either of the two products. These shares (allocation factors) can be determined based on different properties, e.g. product value, carbon or energy content. For carbon dioxide uptake (line 44) 61.3 % of the total amount are allocated to the wheat grains because this equals the amount of carbon found in the grains.

Tab. 8.1 Excerpt of the multi-output process raw data of the wheat production and allocation factors used for the grains and straw (example from Nemecek et al. 2007)

	B	F	G	J	K	Z	AG	AH
3	Explanations	Name	Location	Infrastructure-Process	Unit	wheat IP	wheat grains IP, at farm	wheat straw IP, at farm
4		Location				CH	CH	CH
5		InfrastructureProcess				0	0	0
6		Unit				ha	kg	kg
7	Technosphere	ammonium nitrate, as N, at regional storehouse	RER	0	kg	6.7E+1	92.5	7.5
26		grain drying, low temperature	CH	0	kg	7.6E+1	100.0	-
44	resource, in air	Carbon dioxide, in air			kg	1.4E+4	61.3	38.7
45	resource, biotic	Energy, gross calorific value, in biomass			MJ	1.7E+5	59.1	40.9
46	resource, land	Occupation, arable, non-irrigated			m2a	7.9E+3	92.5	7.5
53	soil, agricultural	Cadmium			kg	3.9E-3	42.2	57.9
54		Chlormequat			kg	2.3E-1	92.5	7.5
72	Outputs	wheat grains IP, at farm	CH	0	kg	6.4E+3	100.0	
73		wheat straw IP, at farm	CH	0	kg	3.9E+3		100.0

Unit process raw data can be derived from the information shown in Table 8.1 For instance, the input of 67 kg "Ammonium nitrate" is multiplied with the allocation factor 92.5% and divided by 6420 kg (the amount of wheat grains per hectare). Hence, 9.7 g ammonium nitrate input is attributed to the production of 1 kg of wheat grains. On the other hand, 1.3 g is attributed to the production of 1 kg of wheat straw. Table 8.2 shows the results of this multiplication.

Tab. 8.1 Example for the unit process raw data derived for the two co-products of "wheat IP". Input and output flows of the multi-output process times allocation factor divided by co-product output equals input and output flows of the derived unit processes (excerpt from Nemecek et al. 2007)

Explanations	Name	Location	Infrastructure-Process	Unit	wheat grains IP, at farm	wheat straw IP, at farm
	Location				CH	CH
	InfrastructureProcess				0	0
	Unit				kg	kg
Technosphere	ammonium nitrate, as N, at regional storehouse	RER	0	kg	9.7E-3	1.3E-3
	grain drying, low temperature	CH	0	kg	1.2E-2	
resource, in air	Carbon dioxide, in air			kg	1.3E+0	1.4E+0
resource, biotic	Energy, gross calorific value, in biomass			MJ	1.5E+1	1.8E+1
resource, land	Occupation, arable, non-irrigated			m2a	1.1E+0	1.5E-1
soil, agricultural	Cadmium			kg	2.6E-7	5.8E-7
	Chlormequat			kg	3.3E-5	4.4E-6
	wheat grains IP, at farm	CH	0	kg	1.0E+0	
	wheat straw IP, at farm	CH	0	kg		1.0E+0

8.2 Characterisation of the main LCI modelling approaches

8.2.1 Evolution of the approaches

More than ten years ago, the relation between an LCA and the appropriate model were discussed and established during the European Union concerted action LCANET (Frischknecht 1997). This distinction was further refined in Frischknecht (1998).

Whereas the descriptive LCA model (type 0, see Table 8.3) is relatively undisputed (theoretically founded in Heijungs 1997), the appropriate modelling approach to model the effects of a decision is still subject to debates. Different views exist which result in rather different LCI models and finally LCA outcomes (Frischknecht 2002). The main point of discussion is whether or not actual economic relations are followed to identify the suppliers in the situation after the decision has been taken. Some proponents of the consequential approach (Ekvall et al. 2004, Ekvall & Weidema 2004, Weidema 2001) use market information and price elasticities to identify those suppliers that are affected by the decision and will increase or decrease their production (without necessarily having an economic (contractual) link to the process under study). Others plea for the consideration of the actual (future) suppliers based on factual economic business-to-business relationships (Frischknecht 1998).

Tab. 8.3 LCA purposes and goals and corresponding LCI models and data, adapted from Frischknecht (1997)

type	goal of the LCA	LCI model	LCI data
0	• environmental reports	complete system at current output • no variation • everything as it is (was)	average environmental performance of technologies involved (particular technologies or technology mixes)
1	• short-term system optimisation • "one extra passenger" problem	short term variation constant: • technology • installed capacity variable: • capacity use	short-term marginal technologies where technology mixes are involved short term marginal environmental performance of the technologies involved
2	• hot spot identification and elimination; • product system optimisation • product development • product system comparison (analysing the *effect* of a choice)	mid-term variation constant: • capacity use • performance of known technologies variable: • installed capacity • technology mixes	mid-term marginal technologies where technology mixes are involved mid-term marginal (=average) environmental performance of technologies involved
3	• long-term (strategic) planning • modelling future processes	long term variation • constant: • capacity use performance of new technologies variable: • installed capacity • technology mixes	anticipated future changes of technologies and technology mixes considered within the entire product system (technology scenario, consistent future) average environmental performance of the (new and existing) technologies involved

The revised ISO standard 14040 mentions the two applications (consequences of possible changes between two alternative products on one hand, and the account of the history of the product on the other) in the informal Appendix A.2. However, the contents of the standards are generally focused on the attributional (average) approach. A recent publication of UNEP-SETAC Life Cycle Initiative on inventory methods in LCA (Lundie et al. 2007) does not favoufr any particular approach, but highlights properties as well as advantages and drawbacks of the different approaches (attributional, consequential).

In the following, the three approaches are characterised. The text is partly taken from Frischknecht (2007).

8.2.2 The attributional approach

The outline of attributional LCI models has been described in depth by Heijungs (1997). Attributional LCI models may be used to describe for instance the life cycle of one litre of fair trade orange juice consumed in France in 2006. It is assumed that this litre is part of the total consumption volume of juice in France (3'230 metric tons of juice concentrate)[25] and not an extra litre. Inputs and outputs will be determined based on the average production situation for the total amount sold in 2006. The product system of such an attributional analysis comprises (theoretically) all farmers involved in harvesting oranges under fair trade conditions, all factories producing fair trade orange juice in 2006, all factories producing packaging materials for this juice, *etc*.

The result of such an LCI (or LCA) provides information about the environmental impacts of farmers, producers, carriers, *etc.* that can be attributed to the consumption of an average litre of fair trade orange juice purchased in France in 2006.

[25] *www.fairtrade.net/juices.html*, information retrieved on March 19, 2009

8.2.3 The consequential approach

The outline of LCI models that describe the changes of a situation caused by a decision, called "consequential approach", has been extensively discussed during an LCA workshop on electricity data in LCI held in Cincinnati, Ohio, USA and during the Internet Life Cycle Assessment - Life Cycle Management (InLCA-LCM) conference in May 2002 (Ekvall 2002). Furthermore, papers have been published by Ekvall (2004) and Ekvall & Weidema (2004). In the final report of the electricity workshop (Curran et al. (2002) the consequential approach is defined as an attempt to estimate how flows to and from the environment will *change* as a result of a decision. A consequential LCA aims to answer the question whether the decision to purchase for instance a litre of fair trade orange juice (instead of conventional orange juice, instead of apple juice, instead of tap water, *etc.*) leads to reduced or increased CO_2-emissions, nitrate and pesticide emissions to water, *etc.* on a global level. For that purpose, factories and farmers need to be identified which will change their production volume due to that particular change in demand. Opposite to the attributional approach, actors (farmers, producers, carriers *etc.*), that are not affected by a change in that demand, are not part of the product system of a consequential LCA.

In other words, the product system does not comprise the world average of fair trade orange farmers but the ones that will increase or decrease their production. It may well include apple farmers as well, if an increase in fair trade orange juice consumption is at the expense of apple juice. It may even include (selected) conventional orange farmers (and no fair trade farmers at all) if the production capacity of fair trade farmers were constrained. In that case, a decision to purchase fair trade orange juice instead of apple juice leads to increased sales (and production) of conventional orange juice, because sales of orange juice as a whole increase but fair trade farmers cannot supply the additional demand. Hence, the additional litre of fair trade orange juice would then be charged with the environmental impacts of an additional litre of conventional orange juice.

We recognise that the consequential approach aims to link micro-economic actions with macro-economic consequences (what happens in the different markets that are affected by a decision?). It requires an LCA that considers market reactions, production volume developments, technology developments *etc*. This information may be delivered by a set of (pre-defined) conditions, by one or several scenarios or with the help of dynamic models. In any case an embedding in a broader range of socio-economic interdependence is required.

The result of an ideal consequential LCI provides information about how an individual (consumption or investment) decision will influence the (global) environment and whether the purchase of a supposed environmentally friendly product is likely to lead to a reduction in overall environmental impacts.

8.2.4 The decisional approach

An alternative definition of the consequential approach remains on the micro-economic level and is described in Frischknecht (1998). It is called *decisional* approach (Frischknecht (2002; 2006; 2007). In contrast to the interpretation of the consequential approach described above, the decisional approach uses the financial and contractual relations between economic actors (business-to-business relations) as the main basis of information. Applied on our case study, namely the decision whether or not to buy fair trade orange juice (instead of conventional orange juice or instead of apple juice), the product system would be modelled as follows: A consumer who chooses to purchase a certain (labelled) product or service, is entitled (or obliged) to accept the environmental impacts that are economically and contractually related to its production.

As a consequence - and this is the main difference to the consequential approach described above -, the orange juice LCI includes fair trade farmers, producers, carriers, *etc*. in any case. If they were not able or not obliged to adjust their total production, an extra consumption might be compensated by a reduced consumption by someone else. With the decisional approach particular economic activities, which are linked to the product through economic and contractual relations, are attributed to an individual additional (or reduced) consumption. The consequential approach as defined in the previous Subsection links a (consumption or investment) decision to its affected economic activities irrespective of the fact whether these affected activities are actually required for the product consumed or invested in, and irrespective of the fact whether direct economic and/or contractual links to the purchased product exist.

The decisional LCA supports an efficient allocation of scarce environmental resources (similar to the price system that helps to allocate the traditional economic resources labour, land and capital). This alone of course does not reduce environmental pressure. Supporting measures introduced on a macro-economic level are necessary. An environmental policy is required that defines reduction targets on emissions and resource consumptions or on environmental impacts (such as global warming). The relative scarcity of the environmental resources can then be operationalised for LCA with the help of life cycle impact assessment methods.

8.3 Data quality requirements

According to ISO 14040 data quality requirements should be specified in the goal and scope definition. These aspects have to be addressed in the guidelines for an EPI as well. These descriptions should cover the following parameters:

- time-related coverage;
- geographical coverage;
- technology coverage.

Furthermore, for studies that intend to make a comparative assertion that is disclosed to the public, the following additional data quality requirements shall be considered:

- precision: measure of the variability of the data values for each data category expressed;
- completeness: percentage of locations reporting primary data from the potential number in existence for each data category unit process;
- representativeness: qualitative assessment of the degree to which the data set reflects the true population of interest;
- consistency: qualitative assessment of how uniformly the study methodology is applied to the various components of the analysis;
- reproducibility: qualitative assessment of the extent to which information on the methodology and data values allows an independent practitioner to reproduce the results reported in the study.

9 References

AFNOR 2008
AFNOR (2008) Principes généraux pour l'affichage environnemental des produits de grande consommation. BP X30-323. AFNOR et ADEME.

Ahmad & Wyckoff 2003
Ahmad N. and Wyckoff A. (2003) Carbon dioxide emissions embodied in international trade of goods. STI working paper 2003/15. OECD Organisation for Economic Cooperation and Development, Paris.

Althaus et al. 2007
Althaus H.-J., Dinkel F., Stettler C. and Werner F. (2007) Life Cycle Inventories of Renewable Materials. ecoinvent report No. 21, v2.0. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, retrieved from: www.ecoinvent.org.

Baccini et al. 1993
Baccini P., Daxbeck H., Glenck E. and Henseler G. (1993) METAPOLIS - Güterumsatz und Stoffwechselprozesse in den Privathaushalten einer Stadt. 34A. Eidgenössische Technische Hochschule-Zürich, Eidg. Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz (EAWAG), Zürich.

Bébié et al. 2009
Bébié B., Lenzlinger M., Frischknecht R., Hartmann C. and Hammer S. (2009) Grundlagen für ein Umsetzungskonzept der 2000-Watt-Gesellschaft am Beispiel der Stadt Zürich. Stadt Zürich, Bundesamt für Energie, EnergieSchweiz für Gemeinden, Novatlantis, Zürich.

Best et al. 2008
Best A., Blobel D., Cavalieri S., Giljum S., Hammer M., Lutter S., Simmons C. and Lewis K. (2008) Potential of the Ecological Footprint for monitoring environmental impacts from natural resource use: Analysis of the potential of the Ecological Footprint and related assessment tools for use in the EU's Thematic Strategy on the Sustainable Use of Natural Resources. Report to the European Commission, DG Environment.

BfS 2007
BfS (2007) Einkommens-und Verbrauchserhebung 2004 (EVE 2004), Kommentierte Ergebnisse und Tabellen. Bundesamt für Statistik, Bern.

Biesot et al. 1995
Biesot W., Moll H. C., Vringer K., Wilting H. C., Blok K., Kok R., Noorman K. J. and Potting J. (1995) Reduction of CO_2 emissions by lifestyle changes. 80. Center for Energy and Environmental Studies of the University of Groningen (IVEM RUG), The Netherlands.

Böge 1995
Böge S. (1995) Erfassung und Bewertung von Transportvorgängen: Die produktbezogene Transportkettenanalyse. In: *Güterverkehr, Logistik und Umwelt, Analysen und Konzepte zum interregionalen und städtischen Verkehr,* Vol. 2. überarbeitete und erweiterte Auflage (Ed. Läpple D.). pp. 113 - 141. sigma Verlag, Berlin.

Boulouchos et al. 2008
Boulouchos K., Casciaro C., Fröhlich K., S. Hellweg, Leibundgut H. and Spreng D. (2008) Energy Strategy for ETH Zurich. ETH Zurich, Energy Science Center, retrieved from: http://www.esc.ethz.ch/box_feeder/StrategyE.pdf.

Boustead & Hancock 1979
Boustead I. and Hancock G. F. (1979) Handbook of Industrial Energy Analysis. Ellis Horwood Ltd., Chichester, England.

BP Amoco 1999
BP Amoco (1999) BP Amoco statistical review of world energy 1998. BP Amoco, London.

Brouwer 1998
Brouwer N. M. (1998) Energy reduction options related to Dutch household food consumption. Wageningen Agricultural University, Wageningen.

Brower & Leon 1999
Brower M. and Leon W. (1999) The Consumer's Guide to Effective Environmental Choices: Practical Advice from the Union of Concerned Scientists - The first comprehensive look at the full range of modern consumer activities, identifying those that cause the most environmental damage and those that cause the least. (ed. Union of Concerned Scientists (UCS)). Three Rivers Press, New York, USA.

Büsser et al. 2008
Büsser S., Steiner R. and Jungbluth N. (2008) LCA of Packed Food Products: the function of flexible packaging: coffee, spinach and butter. ESU-services Ltd. im Auftrag von Flexible Packaging Europe, Düsseldorf, DE and Uster, CH, retrieved from: http://www.flexpack-europe.org/front_content.php?idcat=170.

Büsser & Jungbluth 2009a
Büsser S. and Jungbluth N. (2009a) LCA of Ready-to-Serve Bolognese Lasagne Packed in Aluminium Containers. ESU-services Ltd. commissioned by European Aluminium Foil Association e.V. (EAFA), Düsseldorf, DE and Uster, CH, retrieved from: www.esu-services.ch/cms/index.php?id=packaging.

Büsser & Jungbluth 2009b
Büsser S. and Jungbluth N. (2009b) Aluminium beeinflusst nur gering. *In: alimentaonline*, **2009**(14), pp., retrieved from: www.alimentaonline.ch, www.esu-services.ch/cms/index.php?id=packaging.

C&A 2008
C&A (2008) Acting Responsibly. Report 2008, Dusseldorf/Brussels, retrieved from: http://www.corporateregister.com/.

Calzoni et al. 2000
Calzoni J., Caspersen N., Dercas N., Gaillard G., Gosse G., Hanegraaf M., Heinzer L., Jungk N., Kool A., Korsuize G., Lechner M., Leviel B., Neumayr R., Nielsen A. M., Nielsen P. H., Nikolaou A., Panoutsou C., Panvini A., Patyk A., Rathbauer J., Reinhardt G. A., Riva G., Smedile E., Stettler C., Weidema B. P., Wörgetter M. and van Zeijts H. (2000) Bioenergy for Europe: Which ones fit best? A comparative analysis for the community. Research funded in part by The European Commission in the framework of the FAIR V Programme Contract: CT 98 3832, IFEU – Institut für Energie- und Umweltforschung Heidelberg GmbH.

Carbon Trust & DEFRA 2008
Carbon Trust and DEFRA (2008) PAS 2050:2008: Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. British Standard, BSi, London, retrieved from: http://www.bsi-global.com/en/Standards-and-Publications/Industry-Sectors/Energy/PAS-2050.

Carlsson 1997
Carlsson A. (1997) Weighted Average Source Points and Distances for Consumption Origin - Tools for Environmental Impact Assessment. *In: Ecological Economics*(accepted 1/97), pp.

Carlsson-Kanyama 1999
Carlsson-Kanyama A. (1999) Consumption Patterns and Climate Change: Consequences of eating and travelling in Sweden. Doctoral Thesis. Stockholm University, Sweden.

Carlsson-Kanyama & Faist 2000
Carlsson-Kanyama A. and Faist M. (2000) Energy Use in the Food Sector: A data survey. 291. Environmental Strategies Research Group, Sweden, retrieved from: http://www.esu-services.ch/publications.html#Food.

Chevrot 2000
Chevrot F. (2000) Methodologies: US Case Study on the Environmental Impacts of Household Food Consumption. Massachusetts Institute of Technology, Center for Environmental Initiatives for OECD Environment Directorate, Project on Sustainable Consumption.

Classen & Jungbluth 2002
Classen M. and Jungbluth N. (2002) Bewertung der Wassernutzung und Verschmutzung für Konsumgüter: Fallstudien für Orangensaft, Baumwolle, Papier, Leder, Fleisch und Skitourismus. ESU-services im Auftrag des WWF Schweiz, Uster.

Coley et al. 1997
Coley D. A., Goodliffe E. and Macdiarmid J. (1997) The Embodied Energy of Food: The Role of Diet. *In: Energy Policy*, **26**(6), pp. 455-459.

Curran et al. 2002
Curran M. A., Mann M. K. and Norris G. (2002) Report on the International Workshop on Electricity Data for Life Cycle Inventories. *In proceedings from: Electricity Data for Life Cycle Inventories*, US-EPA, held at the Breidenbach Research Center, Cincinnati, Ohio, USA, October 23-25, 2001.

Doka 2009
Doka G. (2009) Estimates of road, rail and airplane noise damages for Life Cycle Assessment. Doka Life Cycle Assessments, Zurich, retrieved from: www.doka.ch.

ecoinvent Centre 2009
ecoinvent Centre (2009) ecoinvent data v2.1, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland, retrieved from: www.ecoinvent.org.

Edwards et al. 2007
Edwards R., Larivé J.-F., Mahieu V. and Rouveirolles P. (2007) Well-to-wheels analysis of future automotive fuels and power trains in the European context. WTW report Version 2c. Concawe, EUCAR, JRC/IES, retrieved from: http://ies.jrc.cec.eu.int/wtw.html.

Ekvall 2002
Ekvall T. (2002) Limitations of Consequential LCA. *In proceedings from: InLCA/LCM 2002 E-Conference*, May 20-25, 2002, retrieved from: http://www.lcacenter.org/lca-lcm/pdf/Consequential-LCA.pdf.

Ekvall et al. 2004
Ekvall T., Ciroth A., Hofstetter P. and Norris G. (2004) Evaluation of attributional and consequential life cycle assessment. Chalmers University of Technology, Göteborg.

Ekvall & Weidema 2004
Ekvall T. and Weidema B. (2004) System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis. *In: Int. J. Life Cycle Assess*, **9**(3), pp. 161-171, retrieved from: www.scientificjournals.com/sj/lca/welcome.htm.

Electrolux 1997
Electrolux (1997) Certified environmental product declaration for ER 8199B. Electrolux, retrieved from: http://www.environdec.com/reg/e_epd10.pdf.

EPD 2008
EPD (2008) General programme instructions for environmental product declarations, epd. The International EPD Cooperation (IEC), retrieved from: http://www.environdec.com.

Ernst and Young 2009
Ernst and Young (2009) Piste pour un étiquetage environnemental lisible et efficace - Résultat d'enquête consommateur. Retrieved 2009-10-19 retrieved from: http://www.ey.com/Publication/vwLUAssets/Vers_un_etiquetage_environnemental_lisible_et_efficace/$File/Etude_Etiquetage_Environnemental.pdf.

European Commission 2009a
European Commission (2009a) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable resources (Renewable Energy Directive-RED). Commission of the European Communities, Brussels, BE, retrieved from: http://ec.europa.eu/energy/climate_actions/doc/2008_res_directive_en.pdf.

European Commission 2009b
European Commission (2009b) International Reference Life Cycle Data System (ILCD) Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment (LCA). European Commission, DG-JRC, retrieved from: http://lct.jrc.ec.europa.eu/eplca/deliverables/consultation-on-international-reference-life-cycle-data-system-ilcd-handbook.

EUROSTAT 2001
EUROSTAT (2001) Economy-wide material flow accounts and derived indicators; A methodological guide. European Communities, Luxembourg, retrieved from: http:europa.eu.int/comm/eurostat/.

Faist Emmenegger et al. 2003
Faist Emmenegger M., Frischknecht R. and Jungbluth N. (2003) LCA des Mobilfunksystems UMTS. Unter Mitarbeit von M. Guggisberg, Swisscom, M. Stutz, Motorola, T. Otto, Deutsche Telekom, R. Witschi, Swisscom. ESU-services, Uster.

Faist Emmenegger & Frischknecht 2004
Faist Emmenegger M. and Frischknecht R. (2004) Ökobilanz Waschautomat V-ZUG, Uster.

Faist et al. 1999a
Faist M., Kytzia S. and Baccini P. (1999a) The impact of Household Food Consumption on Resource and Energy Management. *In proceedings from: Second International Symposium on Sustainable Household Consumption, Household Metabolism: From concept to application*, Groningen-Paterswolde, The Netherlands, 3-4.6.

Faist et al. 1999b
Faist M., Kytzia S. and Baccini P. (1999b) Resource management in the food production and distribution: the role of food retailers. *In proceedings from: Int. Conference on Industrial Ecology and Sutstainability*, Troyes, 22.-25.9.

Frischknecht et al. 1996
Frischknecht R., Bollens U., Bosshart S., Ciot M., Ciseri L., Doka G., Dones R., Gantner U., Hischier R. and Martin A. (1996) Ökoinventare von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. 3. Gruppe Energie - Stoffe - Umwelt (ESU), Eidgenössische Technische Hochschule Zürich und Sektion Ganzheitliche Systemanalysen, Paul Scherrer Institut, Villigen, Bundesamt für Energie (Hrsg.), Bern, CH, retrieved from: www.energieforschung.ch.

Frischknecht 1997
Frischknecht R. (1997) Goal and scope definition and inventory analysis. In: *Life Cycle Assessment: State-of-the-Art and Research Priorities,* Vol. 1 (Ed. Helias A. Udo de Haes and Nicoline Wrisberg). 1 Edition. pp. 59-88. ecomed publisher, Bayreuth.

Frischknecht 1998
Frischknecht R. (1998) Life Cycle Inventory Analysis for Decision-Making: Scope-Dependent Inventory System Models and Context-Specific Joint Product Allocation. 3-9520661-3-3. Eidgenössische Technische Hochschule Zürich, Switzerland.

Frischknecht & Jungbluth 2000
Frischknecht R. and Jungbluth N. (2000) Globale Umweltkriterien für Ökostrom. ESU-services im Auftrag des Vereins für umweltgerechte Elektrizität, Zürich, Uster, retrieved from: http://www.naturemade.org/Deutsch/Download/downloads_d_oekobilanz.htm.

Frischknecht 2002
Frischknecht R. (2002) An Introduction to Attributional and Consequential LCI Models – Properties and Differences. 17. Diskussionsforum Ökobilanzen, Zürich, retrieved from: http://www.texma.org/LCA-Forum/Documentation/AbstractsDF17.htm.

Frischknecht 2006
Frischknecht R. (2006) Notions on the Design and Use of an Ideal Regional or Global LCA Database. *In: Int. J. Life Cycle Assess*, **11**(Special Issue 1), pp. 40-48.

Frischknecht et al. 2007a
Frischknecht R., Althaus H.-J., Bauer C., Doka G., Heck T., Jungbluth N., Kellenberger D. and Nemecek T. (2007a) The environmental relevance of capital goods in life cycle assessments of products and services. *In: Int. J. LCA*, **Online first**, pp., retrieved from: DOI: http://dx.doi.org/10.1065/lca2007.02.309.

Frischknecht 2007
Frischknecht R. (2007) Modelling of product systems in life cycle inventory analysis: Synopsis of Attributional and Consequential LCI Models - Properties and Differences. Hrsg. Forschungszentrum Karlsruhe, Institut für Technikfolgenabschätzung und Systemanalyse, Zentralabteilung technikbedingte Stoffströme, Uster, Karlsruhe, retrieved from: http://www.netzwerk-lebenszyklusdaten.de/cms/content/site/lca/Home/Aktivitaeten/Projektberichte.

Frischknecht et al. 2007b
Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Dones R., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G. and Spielmann M. (2007b) Overview and Methodology. ecoinvent report No. 1, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht et al. 2007c
Frischknecht R., Jungbluth N., Althaus H.-J., Bauer C., Doka G., Dones R., Hellweg S., Hischier R., Humbert S., Margni M. and Nemecek T. (2007c) Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht et al. 2008
Frischknecht R., Steiner R. and Jungbluth N. (2008) Methode der ökologischen Knappheit - Ökofaktoren 2006. Umwelt-Wissen Nr. 0906. Bundesamt für Umwelt (BAFU), Bern, retrieved from: http://www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=de.

Frischknecht et al. 2009a
Frischknecht R., Jungbluth N. and Pfister S. (2009a) UBP-Bewertung für den Wasserbedarf von Treibstoffen (Entwurf). ESU-services, Uster, im Auftrag des Bundesamtes für Umwelt (BAFU), Bern, CH.

Frischknecht et al. 2009b
Frischknecht R., Steiner R. and Jungbluth N. (2009b) The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Federal Office for the Environment FOEN, Zürich und Bern, retrieved from: http://www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=en.

Frischknecht 2009
Frischknecht R. (2009) Teil 2: Ökobilanzen (Life cycle assessment, LCA). ETH Zürich Studiengang Umweltnaturwissenschaften, retrieved from: www.esu-services.ch.

Frischknecht & Leuenberger 2009
Frischknecht R. and Leuenberger M. (2009) Elektroauto... Königsweg oder Sackgasse? Fragen und Antworten der Ökobilanz von Elektroautos. ESU-services, Uster, Vortrag im Auftrag Arbeitskreis Umwelt MitarbeiterInnen, Daimler AG, Uster, CH, retrieved from: http://www.esu-services.ch/cms/index.php?id=energy.

Global Footprint Network 2009
Global Footprint Network (2009) Ecological Footprint Standards 2009. Global Footprint Network, Oakland, retrieved from: www.footprintstandards.org.

Goedkoop & Spriensma 2000
Goedkoop M. and Spriensma R. (2000) The Eco-indicator 99: A damage oriented method for life cycle impact assessment. PRé Consultants, Amersfoort, The Netherlands, retrieved from: www.pre.nl/eco-indicator99/.

Goedkoop et al. 2009
Goedkoop M., Heijungs R., Huijbregts M. A. J., De Schryver A., Struijs J. and van Zelm R. (2009) ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition. Report I: Characterisation, NL, retrieved from: http://lcia-recipe.net/.

Grießhammer & Hochfeld 2009
Grießhammer R. and Hochfeld C. (2009) Memorandum Product Carbon Footprint. Öko-Institut, Berlin, retrieved from: www.oeko.de.

Guinée et al. 2001
Guinée J. B., (final editor), Gorrée M., Heijungs R., Huppes G., Kleijn R., de Koning A., van Oers L., Wegener Sleeswijk A., Suh S., Udo de Haes H. A., de Bruijn H., van Duin R., Huijbregts M. A. J., Lindeijer E., Roorda A. A. H. and Weidema B. P. (2001) Life cycle assessment; An operational guide to the ISO standards; Parts 1 and 2. Ministry of Housing, Spatial Planning and Environment (VROM) and Centre of Environmental Science (CML), Den Haag and Leiden, The Netherlands, retrieved from: http://www.leidenuniv.nl/cml/ssp/projects/lca2/lca2.html.

H&M 2004
H&M (2004) Corporate Social Responsibility Report 2004, retrieved from: http://www.corporateregister.com/.

H&M 2005
H&M (2005) Corporate Social Responsibility Report 2005, retrieved from: http://www.corporateregister.com/.

Habersatter et al. 1998
Habersatter K., Fecker I., Dall`Acqua S., Fawer M., Fallscheer F., Förster R., Maillefer C., Ménard M., Reusser L. and Som C. (1998) Ökoinventare für Verpackungen. 250, 2. korrigierte und aktualisierte Auflage. Bundesamt für Umwelt, Wald und Landschaft, Bern, Schweiz.

Hauschild & Wenzel 1997
Hauschild M. and Wenzel H. (1997) Environmental Assessment of Products. Vol. 2: Scientific background. Chapman & Hall, London, Weinheim, New York.

Hauschild et al. 2009
Hauschild M., Goedkoop M., Guinée J., Heijungs R., Huijbregts M. A. J., Jolliet O., Margni M. and De Schryver A. (2009) Framework and requirements for Life Cycle Impact Assessment (LCIA) models and indicators. European Commission - DG Joint Research Centre, JRC, Institute for Environment and Sustainability (IES), retrieved from: http://lct.jrc.ec.europa.eu/eplca/deliverables/consultation-on-international-reference-life-cycle-data-system-ilcd-handbook.

Heijungs 1997
Heijungs R. (1997) Economic drama and the environmental stage; Formal derivation of algorithmic tools for environmental analysis and decision-support from a unified epistemological principle. Centre for Environmental Sciences, Leiden University, Leiden.

Hertwich & Peters 2009
Hertwich E. and Peters G. (2009) Carbon Footprint of Nations: A Global, Trade-Linked Analysis. *In: Environ. Sci. Technol.*, **online first**, pp.

Hofstetter 1992
Hofstetter P. (1992) Persönliche Energie- und CO_2-Bilanz. Fragebogen und Kommentar zur Bestimmung des privaten Energieverbrauchs und CO_2-Ausstosses. Aktion Klimaschutz, Zürich, Schweiz, retrieved from: www.proclim.unibe.ch/facts/pcc/index.html.

Hofstetter 1998
Hofstetter P. (1998) Perspectives in Life Cycle Impact Assessment: A structured approach to combine models of the technosphere, ecosphere and valuesphere. Kluwer Academic Publishers, ISBN 0-7923-8377-X, Boston, Dordrecht, London.

Horngren 1991
Horngren C. T., Foster, G. (1991) Cost Accounting, A Managerial Emphasis, 7th edition. Prentice Hall International Inc.

Huijbregts 1999
Huijbregts M. A. J. (1999) Priority assessment of toxic substances in the frame of LCA: Development and application of the multi-media fate, exposure and effect model USES-LCA. University of Amsterdam, Amsterdam, retrieved from: www.leidenuniv.nl/interfac/cml/lca2/.

Huijbregts et al. 2006
Huijbregts M. A. J., Rombouts L. J. A., Hellweg S., Frischknecht R., Hendriks A. J., van de Meent D., Ragas A. M. J., Reijnders L. and Struijs J. (2006) Is Cumulative Fossil Energy Demand a Useful Indicator for the Environmental Performance of Products?,. *In: Environ. Sci. Technol.*, **40**(3), pp. 641-648, retrieved from: http://pubs.acs.org/cgi-bin/abstract.cgi/esthag/2006/40/i03/abs/es051689g.html.

Huijbregts et al. 2007
Huijbregts M. A. J., Hellweg S., Frischknecht R., Hungerbühler K. and Hendriks A. J. (2007) Ecological Footprint Accounting in the Life Cycle Assessment of Products. *In: Ecological Economics*, pp., retrieved from: doi:10.1016/j.ecolecon.2007.04.017.

Hunt 1974
Hunt R. G. (1974) Resource and Environmental Profile Analysis of Nine Beverage Container Alternatives. Midwest Research Institute for U.S. Environmental Protection Agency, Washington D.C.

IDARio 2000
IDARio (2000) Umsetzung der Strategie des Bundesrates zur nachhaltigen Entwicklung, Massnahme Nr. 6 "Anerkennung und Förderung von Labels". Interdepartementaler Ausschuss Rio (IDARio), Bern.

International Organization for Standardization (ISO) 2000
International Organization for Standardization (ISO) (2000) Environmental Labels and Declarations. ISO/WD 14020-24.

International Organization for Standardization (ISO) 2006a
International Organization for Standardization (ISO) (2006a) Environmental management - Life cycle assessment - Principles and framework. ISO 14040:2006; Second Edition 2006-06, Geneva.

International Organization for Standardization (ISO) 2006b
International Organization for Standardization (ISO) (2006b) Environmental management - Life cycle assessment - Requirements and guidelines. ISO 14044:2006; First edition 2006-07-01, Geneva.

International Organization for Standardization (ISO) 2006c
International Organization for Standardization (ISO) (2006c) Environmental Labels and Declarations - Type III environmental declarations - Principles and procedures. ISO/WD 14025.

International Organization for Standardization (ISO) 2009
International Organization for Standardization (ISO) (2009) Carbon Footprint of products. ISO/WD 14067: working draft.

Jungbluth 1997
Jungbluth N. (1997) Life-Cycle-Assessment for Stoves and Ovens. UNS-Working Paper No. 16. Eidgenössische Technische Hochschule, Zürich, retrieved from: www.esu-services.ch.

Jungbluth et al. 2000
Jungbluth N., Tietje O. and Scholz R. (2000) Food Purchases: Impacts from the Consumers' Point of View Investigated with a Modular LCA. *In: Int J LCA*, **5**(3), pp. 134-142, retrieved from: www.esu-services.ch.

Jungbluth & Frischknecht 2000
Jungbluth N. and Frischknecht R. (2000) Environmental Impacts from Household Food Consumption: Methodologies for Evaluation and Indicators for Monitoring. ESU-services for OECD Environment Directorate, Project on Sustainable Consumption, Uster, retrieved from: www.esu-services.ch.

Jungbluth 2000
Jungbluth N. (2000) Umweltfolgen des Nahrungsmittelkonsums: Beurteilung von Produktmerkmalen auf Grundlage einer modularen Ökobilanz. Dissertation Nr. 13499. Eidgenössische Technische Hochschule Zürich, Umweltnatur- und Umweltsozialwissenschaften, dissertation.de, Berlin, D, retrieved from: www.jungbluth.de.vu.

Jungbluth & Faist Emmenegger 2005
Jungbluth N. and Faist Emmenegger M. (2005) Ökobilanz Trinkwasser - Mineralwasser. ESU-services Gmbh im Auftrag des Schweizerischer Verein des Gas- und Wasserfaches SVGW.

Jungbluth et al. 2007a
Jungbluth N., Chudacoff M., Dauriat A., Dinkel F., Doka G., Faist Emmenegger M., Gnansounou E., Kljun N., Schleiss K., Spielmann M., Stettler C. and Sutter J. (2007a) Life Cycle Inventories of Bioenergy. ecoinvent report No. 17, v2.0. ESU-services, Uster, CH, retrieved from: www.ecoinvent.org.

Jungbluth et al. 2007b
Jungbluth N., Frischknecht R., Faist Emmenegger M. and Tuchschmid M. (2007b) Life Cycle Assessment of BTL-fuel production: Goal and Scope Definition (revised). RENEW - Renewable Fuels for Advanced Powertrains, Sixth Framework Programme: Sustainable Energy Systems, Deliverable: D 5.2.2. ESU-services Ltd., Uster, retrieved from: www.esu-services.ch/renew.htm.

Jungbluth et al. 2007c
Jungbluth N., Steiner R. and Frischknecht R. (2007c) Graue Treibhausgas-Emissionen der Schweiz: 1990 bis 2004: Erweiterte und aktualisierte Bilanz. UW-0711. ESU-services, Uster, im Auftrag des Bundesamtes für Umwelt (BAFU), Bern, CH, retrieved from: http://www.umwelt-schweiz.ch/uw-0711-d, http://www.esu-services.ch/cms/index.php?id=graue-emissionen&L=0.

Jungbluth et al. 2008
Jungbluth N., Büsser S., Frischknecht R. and Tuchschmid M. (2008) Ökobilanz von Energieprodukten: Life Cycle Assessment of biomass-to-liquid fuels. 280006. ESU-services Ltd. im Auftrag des Bundesamt für Energie, Bundesamt für Umwelt und Bundesamt für Landwirtschaft, Berne, CH, retrieved from: http://www.esu-services.ch/btl.

Jungbluth et al. 2010a
Jungbluth N., Büsser S., Stucki M. and Leuenberger M. (2010a) Life cycle inventories of food consumption: EcoSpold LCI database of ESU-services. ESU-services Ltd., Uster, CH, retrieved from: http://www.esu-services.ch/inventories.htm.

Jungbluth et al. 2010b
Jungbluth N., Frischknecht R., Orthlieb A., Büsser S. and Leuenberger M. (2010b) Aktualisierung und Ergänzung der naturemade Kennwertmodelle: Ökobilanzen für die Prüfung des globalen Kriteriums von Energieprodukten (Zwischenbericht Juli 2010). ESU-services im Auftrag vom Verein für umweltgerechte Energie (VUE), Uster, retrieved from: http://www.esu-services.ch/cms/index.php?id=naturemade.

Jungbluth et al. 2011
Jungbluth N., Nathani C., Stucki M. and Leuenberger M. (2011) Environmental impacts of consumption and production in Switzerland: environmentally extended input-output-analysis. (under preparation). ESU-services GmbH & Rütter+Partner, im Auftrag des Bundesamtes für Umwelt (BAFU), Bern, CH.

Kägi et al. 2007
Kägi T., Ruth Freiermuth-Knuchel, Nemecek T. and Gaillard G. (2007) Ökobilanz von Energiepflanzen. *In: Agrarforschung*, **14**(10), pp. 460-465, retrieved from: http://www.agrarforschung.ch/de/inh_det.php?id=1318.

Känzig & Jolliet 2006
Känzig J. and Jolliet O. (2006) Umweltbewusster Konsum: Schlüsselentscheide, Akteure und Konsummodelle. Umwelt-Wissen Nr. 0616. Bundesamt für Umwelt (BAFU), Bern, retrieved from: www.bafu.admin.ch/dokumentation/medieninformation/00962/index.html?lang=de&msg-id=19128.

Känzig & Hauser 2009
Känzig J. and Hauser A. (2009) Darlegung der Umweltbelastung - True and Fair View und Umweltbelastungszeiten. Präsentation 29. Juni 2009, BAFU, Bern.

KarstadtQuelleAG 2005
KarstadtQuelleAG (2005) Sustainability Report 2005, Essen, Germany, retrieved from: http://www.corporateregister.com/.

Kauffman & Chevrot 2000
Kauffman J. and Chevrot F. (2000) The Environmental Impacts of Household Food Consumption: The case of the United States. Massachusetts Institute of Technology, Center for Environmental Initiatives for OECD Environment Directorate, Project on Sustainable Consumption.

KBOB 2009
KBOB (2009) Ökobilanzdaten im Baubereich. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: http://www.bbl.admin.ch/kbob/00493/00495/index.html?lang=de.

Knoepfel 1995
Knoepfel I. (1995) Grundlagenuntersuchungen zum direkten und indirekten Energieverbrauch der privaten Haushalte: Ansätze zur Quantifizierung und zur sozioökonomischen Differenzierung für die Schweiz. Inst. f. Energietechnik, LES, Eidgenössische Technische Hochschule, Zürich.

Kramer & Moll 1995
Kramer K. J. and Moll H. C. (1995) Energie voedt: nadere analyses van het indirecte energieverbruik van voeding. 77. Center for Energy and Environmental Studies of the University of Groningen (IVEM RUG), The Netherlands.

Kramer et al. 1998
Kramer K. J., Moll H. C. and Nonhebel S. (1998) Total Greenhouse Gas Emissions related to Dutch Crop Production System. *In: Agriculture, Ecosystems and Environment*, **72**(1), pp. 9-16.

Kramer 1998
Kramer K. J. (1998) Options to reduce the energy use and greenhouse gas emissions related to Dutch household food consumption. 9801. IVEM, Groningen.

Kramer et al. 1999
Kramer K. J., Moll H. C., Nonhebel S. and Wilting H. C. (1999) Greenhouse gas emissions related to Dutch food consumption. *In: Energy Policy*, **27**(4), pp. 203-216.

L-B-Systemtechnik et al. 2002
L-B-Systemtechnik, Choudhury R., Wurster R., Schindler J., Miller M., Brinkman N., Armstrong A., Rckead D., Jersey G., Kerby M., Khehgi H., Robbins J., Cadu J. and Breton D. L. (2002) GM Well-to-Wheel Analysis of Energy Use and Greenhouse Gas Emissions of Advanced Fuel/ Vehicle Systems - A European Study. L-B-Systemtechnik GmbH, Ottobrunn, DE, retrieved from: www.lbst.de/gm-wtw.

Leach 1976
Leach G. (1976) Energy and Food Production. IPC Science and Technology Press, Surrey, Great Britain.

Leontief 1936
Leontief W. (1936) Quantitative Input-Output Relations in the Economic System of the United States. *In: Review of Economics and Statistics*(3), pp. 105-125.

Loske & Bleischwitz 1996
Loske R. and Bleischwitz R. (1996) Zukunftsfähiges Deutschland. Ein Beitrag zu einer global nachhaltigen Entwicklung. (ed. BUND und Misereor). Wuppertal Institut für Klima, Umwelt, Energie GmbH, ISBN 3-7643-5278-7, Birkhäuser Verlag, Basel, Boston, Berlin.

Lundie et al. 2007
Lundie S., Ciroth A. and Huppes G. (2007) Inventory Methods in LCA: towards consistency and improvement. UNEP-SETAC Life Cycle Initiative, Paris, retrieved from: http://lcinitiative.unep.fr/includes/file.asp?site=lcinit&file=1DBE10DB-888A-4891-9C52-102966464F8D.

Margni et al. 2003
Margni M., Humbert S., Payet J., Pennington D. W., Rebitzer G., Rosenbaum R. and Jolliet.O. (2003) IMPACT 2002+: A Life Cycle Impact Assessment Methodology. Ecole Polytechnique Fédérale de Lausanne, EPFL, Lausanne, CH, retrieved from: http://www.sph.umich.edu/riskcenter/jolliet/impact2002+.htm.

Mila i Canals et al. 2007
Mila i Canals L., Hospido A., Clift R., Truninger M., Hounsome B. and Edwards-Jones G. (2007) Environmental effects and consumer considerations of consuming lettuce in the UK winter. *In proceedings from: LCA foods 2007*, Gothenburg.

Mill 1848
Mill J. S. (1848) Principles of Political Economy; With Some of Their Applications to Social Philosophy. Vol. II. John W. Parker, West Strand, London.

Nathani et al. 2008
Nathani C., van Nieuwkoop R. and Wickart M. (2008) Revision der IOT 2001 und Schätzung einer IOT 2005 für die Schweiz. Rütter & Partner, ecoplan, cepe, Rüschlikon / Bern / Zürich, retrieved from: http://www.bfs.admin.ch/bfs/portal/de/index/themen/04/22/publ.Document.117273.pdf.

Nemecek et al. 2007
Nemecek T., Heil A., Huguenin O., Meier S., Erzinger S., Blaser S., Dux. D. and Zimmermann A. (2007) Life Cycle Inventories of Agricultural Production Systems. ecoinvent report No. 15, v2.0. Agroscope FAL Reckenholz and FAT Taenikon, Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Norris 1998
Norris G. A. (1998) Direct and Upstream Emissions of Carbon Dioxide from Fossil Fuel Combustion: An Input/Output-based Assessment and Comparison of Sectors in the US Economy. 159614. National Renewable Energy Laboratory, North Berwick, Maine, USA.

OECD 1997
OECD (1997) Sustainable Consumption and Production: Clarifying the Concepts. Organisation for Economic Co-operation and Development (OECD), Paris, retrieved from: www.oecd.org/env/consumption/docs/rosendal.pdf.

Öko-Institut 2009
Öko-Institut (2009) Global Emission Model for Integrated Systems; GEMIS 4.5, Darmstadt, retrieved from: http://www.oeko.de/service/gemis/.

PCR CPC 17 2007
PCR CPC 17 (2007) Product Category Rules (PCR) for preparing an Environmental Product Declaration (EPD) for Electricity, Steam, and Hot and Cold Water Generation and Distribution. The International EPD Consortium (IEC), retrieved from: www.environdec.com.

Pfister et al. 2009
Pfister S., Koehler A. and Hellweg S. (2009) Assessing the environmental impacts of freshwater consumption in LCA. *In: Environ. Sci. Technol.*, **43**(11), pp. 4098–4104.

Picard 2008
Picard C. (2008) The Casino Carbon Footprint, The 1st Complete Environmental Labelling Scheme in France. *In proceedings from: Green Spider Annual Meeting*, Annecy, retrieved from: http://ec.europa.eu/environment/networks/greenspider/doc/am_2008/am08_pres_indice_carbone_casino.pdf.

Pimentel 1973
Pimentel D. (1973) Food Production and the Energy Crisis. *In: Science*, **182**(4111), pp. 443-449.

Pimentel & Pimentel 1996
Pimentel D. and Pimentel M. (1996) Food,Energy and Society. revised Edition. University Press of Colorado, Niwot,Colorado,USA.

PRé Consultants 2009
PRé Consultants (2009) SimaPro 7.1.8, Amersfoort, NL, retrieved from: http://www.esu-services.ch/simapro/.

Probst 1998
Probst B. (1998) Ökologische Beurteilung unterschiedlicher Produktionssysteme von Brot unter besonderer Berücksichtigung Regionaler Produktion: Ein Vergleich auf Basis der Ökobilanzierung. Diplomarbeit. Universität Bern, Bern.

Rubli et al. 2005
Rubli S., Jungbluth N. and Demarne A.-M. M. (2005) Materialflussrechnung für die Schweiz: Machbarkeitsstudie. Bestellnummer: 672-0500-05 / ISBN: 3-303-02089-2. Wertstoff-Börse GmbH, ESU-services im Auftrag des Bundesamtes für Statistik, Uster, retrieved from: http://www.bfs.admin.ch/bfs/portal/de/index/themen/raum_und_umwelt/umweltmanagement_und/blank/publikationen.html?publicationID=1811.

Schmidt-Bleek et. al. 1996
Schmidt-Bleek et. al. F. (1996) MAIA (Einführung in die Material Intensitäts-Analyse nach dem MIPS - Konzept). Wuppertal Institut, Wuppertal.

Schmitz et al. 1995
Schmitz S., Oels H.-J. and Tiedemann A. (1995) Ökobilanz für Getränkeverpackungen. 52/95. Umweltbundesamt, Berlin.

Schweizerischer Bauernverband 1999
Schweizerischer Bauernverband (1999) Statistische Erhebungen und Schätzungen - über Landwirtschaft und Ernährung 1998. Abt. Statistik, Brugg.

Singh 1986
Singh R. P. (1986) Energy in food processing. Elsevier, Amsterdam,Oxford,New York and Tokyo.

Solomon et al. 2007
Solomon S., Qin D., Manning M., Alley R. B., Berntsen T., Bindoff N. L., Chen Z., Chidthaisong A., Gregory J. M., Hegerl G. C., Heimann M., Hewitson B., Hoskins B. J., Joos F., Jouzel J., Kattsov V., Lohmann U., Matsuno T., Molina M., Nicholls N., Overpeck J., Raga G., Ramaswamy V., Ren J., Rusticucci M., Somerville R., Stocker T. F., Whetton P., Wood R. A. and Wratt D. (2007) Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernemental Panel on Climate Change (IPCC)*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Spielmann et al. 2007
Spielmann M., Roberto Dones, Bauer C. and Tuchschmid M. (2007) Life Cycle Inventories of Transport Services. ecoinvent report No. 14, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Stadig 1998
Stadig M. (1998) Life-cycle-assessment of apple production in Sweden, New Zealand and France. The Swedish Inst. for Food and Biotechnology, Göteborg.

Steen 1999
Steen B. (1999) A systematic approach to environmental priority strategies in product development (EPS): Version 2000 – General system characteristics. 1999:4. Centre for Environmental Assessment of Products and Material Systems (CPM), Chalmers University of Technology, Gotheburg, Sweden, retrieved from: http://www.cpm.chalmers.se/html/publication.html.

Steiner et al. 2005
Steiner R., Faist Emmenegger M. and Frischknecht R. (2005) Ökobilanz Kombi-Kühlschrank Electrolux ERB3105, Uster, retrieved from: http://web484.login-27.hoststar.ch/files/Kuehlschrank_Graue_Energie_ESU_Bericht_1.0.pdf.

Sutter et al. 2009
Sutter D., Heldstab J., Nathani C. and Holzhey M. (2009) NAMEA-AIR: Treibhausgasemissionen der Wirtschaftsbranchen - Methodikhandbuch. Schlussbericht an das BFS, Zürich, Rüschlikon.

Tanner & Jungbluth 2003
Tanner C. and Jungbluth N. (2003) Evidence for the Coincidence Effect in Environmental Judgments: Why Isn't It Easy to Correctly Identify Environmentally Friendly Food Products? *In: J. of Experimental Psychology*, **9**(1), pp. 3-11, retrieved from: DOI: 10.1037/1076-898X.9.1.3.

Tanner 2006
Tanner C. (2006) Wenn Konsumentinnen und Konsumenten die Umweltverträglichkeit von Lebensmitteln beurteilen. *In: GAIA*, **15**(3), pp. 215-220.

Tanner 2008
Tanner C. (2008) Context Effects in Environmental Judgments: Assimilation and Contrast Effects in Separate and Joint Evaluation Modes. *In: Journal of applied social psychology*, **38**(11), pp. 2759ff.

Tukker et al. 2006
Tukker A., Huppes G., Guinée J., Heijungs R., Koning A. d., Oers L. v., Suh S., Geerken T., Holderbeke M. V., Jansen B. and Nielsen P. (2006) Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25, retrieved from: http://ec.europa.eu/environment/ipp/identifying.htm.

van der Voet et al. 2005
van der Voet E., Oers L. v., Moll S., Schütz H., Bringezu S., Bruyn S. d., Sevenster M. and Warringa G. (2005) Policy Review on Decoupling: Development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries, retrieved from: http://www.leidenuniv.nl/cml/ssp/projects/dematerialisation/index.html.

van Engelenburg et al. 1994
van Engelenburg B. C. W., van Rossum T. F. M., Blok K. and Vringer K. (1994) Calculating the energy requirements of household purchases. *In: Energy Policy*, **22**(8), pp. 648-656.

VDI 1997
VDI (1997) Cumulative Energy Demand - Terms, Definitions, Methods of Calculation. In: *VDI-Richtlinien 4600*. Verein Deutscher Ingenieure, Düsseldorf.

Visschers et al. 2009
Visschers V., Tobler C., Cousin M. E., Brunner T., Orlow P. and Siegrist M. (2009) Konsumverhalten und Förderung des umweltverträglichen Konsums. Bericht im Auftrag des Bundesamtes für Umwelt BAFU, Consumer Behavior, ETH Zürich, Zürich, retrieved from: www.cb.ethz.ch/publication.

von Stokar et al. 2006
von Stokar T., Myriam Steinemann, Rüegg B. and Schmill J. (2006) Der ökologische Fussabdruck der Schweiz: Ein Beitrag zur Nachhaltigkeitsdiskussion. Bundesamt für Statistik, Neuchâtel, retrieved from: http://www.bfs.admin.ch/bfs/portal/de/index/themen/21/22/lexi.Document.86629.pdf.

VSGP et al. 1999
VSGP, Kommission für Produktionskostenberechnung, Schweizerische Zentralstelle für Gemüsebau (SZG) and Forschungsinstitut für biologischen Landbau (FiBL) (1999) Berechnung der Produktionskosten von Gemüsearten 1999, Koppigen.

VSGP et al. 2009
VSGP, Arbeitsgruppe Betriebswirtschaft and Schweizerische Zentralstelle für Gemüsebau und Spezialkulturen (SZG) (2009) Produktionskosten Gemüse: Daten zur Kalkulation der Produktionskosten und Deckungsbeiträge, Koppigen.

Wackernagel et al. 1996
Wackernagel M., Rees W. and Testemale P. I. (1996) Our Ecological Footprint - Reducing Human Impact on the Earth. New Society Publishers, Philadelphia, PA, and Gabriola Island, BC, Canada.

Wackernagel et al. 2000a
Wackernagel M., Dholakia R., Deumling D. and Richardson D. (2000a) Assess your Household's Ecological Footprint, San Francisco and Centre for Sustainability Studies, Xalapa, retrieved from: www.rprogress.org.

Wackernagel et al. 2000b
Wackernagel M., Linares A. C., Deumling D., Sánchez M. A. V., Falfán I. S. L. and Loh J. (2000b) Ecological Footprints and Ecological Capacities of 152 Nations: The 1996 Update - Summary only. Redefining Progress, San Francisco, USA, Centro de Estudios para la Sustentabilidad, Xalapa, Mexico, WWF International, Gland, Switzerland.

Wada 1993
Wada Y. (1993) The appropriated carrying capacity of tomato production: The ecological footprint of hydroponic greenhouse versus mechanized open field operations. Master Thesis. UBC School of Community and Regional Planning, Vancouver.

Walser 2009
Walser T. (2009) Personal communication. ETH Zurich, Zurich.

Weber et al. 1996a
Weber C., Gebhardt B., Schuler A., Fahl U. and Voß A. (1996a) Energy consumption and airborne emissions in a consumer perspective. 30. Institut für Energiewirtschaft und Rationelle Energieanwendung, Stuttgart.

Weber et al. 1996b
Weber C., Gebhardt B., Schuler A., Schulze T., Fahl U., Voß A., Perrels A., Arkel W. v., Pellekaan W., O`Connor M., Schenk E. and Ryan G. (1996b) Consumers` Lifestyles and Pollutant Emissions. 32. Institut für Energiewirtschaft und Rationelle Energieanwendung, Stuttgart.

Wilting 1996
Wilting H. C. (1996) An Energy Perspective on Economic Activities. Ph.D. Thesis. University of Groningen, The Netherlands.

Zaccheddu 1997
Zaccheddu E. (1997) Bestimmung des Energieverbrauchs für die Schweizer Konsummuster - Anwendung und Anpassung einer holländischen Hybridmethode auf Schweizer Verhältnisse. Diplomarbeit. Eidgenössische Technische Hochschule, Zürich.

Zah et al. 2007
Zah R., Böni H., Gauch M., Hischier R., Lehmann M. and Wäger P. (2007) Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen. Schlussbericht. Abteilung Technologie und Gesellschaft, Empa im Auftrag des Bundesamtes für Energie, des Bundesamtes für Umwelt und des Bundesamtes für Landwirtschaft, Bern, retrieved from: http://www.bfe.admin.ch/energie/00588/00589/00644/index.html?lang=de&msg-id=12653.

Zamboni 1994
Zamboni M. (1994) Grobabschätzung des Energieaufwandes für die Bereitstellung von ausgewählten Getränken und Nahrungsmitteln. im Auftrag von Greenpeace Schweiz und des Konsumentinnenforums Schweiz, Zürich.