Material Footprint of a Sustainable Nutrition System in 2050 – Need for Dynamic Innovations in Production, Consumption and Politics

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Abstract

The field of nutrition is facing numerous social, ecological and economic challenges in the coming decades. The food industry belongs to the most significant economic sectors worldwide and the increasing population of 9 billion in 2050 will cause a growing demand on food. So far, changing lifestyles, especially the global rising consumption of meat and dairy products are increasing environmental damage. Moreover our health and wellbeing are the direct result of healthy or unhealthy nourishment and influence follow-up indicators like individual and public health, the expense of the health sector and work productivity.

The material footprint is a tool to measure and optimize the resource consumption of both products and their ingredients and the production processes along the whole value chain. It covers the whole life cycle of the products, from the extraction of raw materials to the processing industry, distribution, consumption, recycling, and disposal. In order to decrease resource consumption to a level in line with the planetary boundaries, the material footprint of household consumption should achieve a level of six to eight tonnes per capita in a year by 2050. This means a reduction in natural resource consumption by a factor of 5 to 10 in Western European countries. In order to ensure a decent lifestyle for all people in 2050, also the material footprint of nutrition has to be reduced significantly by 2050.

The paper shows the relevance and role of nutrition in the overall material footprint of households on the basis of existing studies on the overall resource consumption caused by household consumption. Quantified meal and diet examples are given. It also discusses the causes of food waste and raises the question how a reduction of food waste is possible and can help decreasing the resource consumption in the food sector.

On the basis of this, requirements are developed nutrition has to meet in 2050 in order to achieve a sustainable level of natural resource use. E.g. by eating 600 kg of food with an average material footprint of 5 kg/kg a food-related resource consumption level of three tonnes per capita in a year could be achieved. The paper discusses options to achieve these requirements as well as dynamics and innovations that are needed from the perspective of production, consumption and politics. It discusses practical implications of a sustainable resource use in nutrition and gives recommendations on how to proceed towards it. Resource efficiency and waste prevention potentials in food chain as well as other requirements for a sustainable level of resource use in nutrition are discussed.

Keywords: *foodstuff, nutrition, value-chain management, resource-efficiency, material footprint, natural resource use, factor 10, sustainability*

1 Introduction

1.1 The challenge of sustainable resource use

The field of nutrition and the food industry, on of the most significant economic sectors worldwide, are facing numerous social, ecological and economic challenges nowadays and in the coming decades. The increasing population of estimated 9 billion in 2050 will cause a growing demand on food although arable land is tending to decrease and land use for competing, e.g. energy crops is increasing (Foresight 2011). This affects rising prices and social problems related to these. In addition, increasing prosperity and changing lifestyles, especially the global rising consumption of meat and dairy products, are even increasing the demand for crop production, thus fostering environmental damage like erosion, soil degradation, resource depletion, biodiversity reduction, climate change, etc. (Foresight 2011). More prosperous nutrition habits in industrialised and industrialising countries can result in even unhealthy nourishment and influence follow-up indicators like individual and public health, the expense of the health sector and last but not least work productivity.

It is indisputable that there is a need for the radical dematerialisation of our Western societies in order to achieve an ecologically and socially sustainable resource use on global level (Schmidt-Bleek 1993, Schmidt-Bleek 2009). Global resource use has to be adapted to the environmental space available (Moffat 1996). This means that resource use should happen within the limit provided by one planet in the long term and resources should be shared among the world population in a way that ensures a sufficient life for all people. The food sector is responsible for a significant share of the resource consumption of a society, in Europe the food sector's (including the value chains of food and beverage) share of greenhouse gas emissions is about 17 % and its resource consumption amounts to appr. 28% (KOM(2011) 571). Due to its share, and even more due to the fact that the consumption of food cannot be stopped completely, it is necessary to consider this sector intensively. As the present resource consumption of the food sector cannot be taken for granted in terms of a sustainable future, a sustainable level of resource use for nutrition has to be defined.

Table 1.
Worldwide development of calorie consumption expected until 2030.
Source: Pricewaterhouse Coopers 2011

Region	**Annual** GDP growth rate per capita (in %)		**Growth** 1999-2030 (in %)		
	1997/1999-2015	2015-2030	population	consumption of calories per capita	total calorie consumption
world	**2,3**	**2,9**	**40,2**	**8,8**	**52,3**
developing countries	**3,7**	**4,4**	**50,2**	**11,2**	**67,0**
• sub-Saharan Africa	1,8	2,3	114,1	15,7	147,8
• Middle East and North Africa	1,8	2,4	72,7	5,5	82,1
• Latin America and the Caribbean	2,8	3,5	44,0	11,2	60,1
• South Asia	3,9	4,3	53,5	20,7	85,2
• East Asia	5,3	5,8	25,2	9,2	36,7
developed countries	**2,6**	**2,8**	**9,8**	**3,6**	**13,6**
emerging countries	**4,0**	**4,3**	**-7,7**	**9,4**	**1,0**

The worldwide demand for resources is mainly governed by world population and the level of prosperity. The latter has a great effect on manners of nutrition, housing and mobility and thus determines the consumption of resources per capita. Population as well as economic performance reside on a worldwide long-term path of growth. Tab. 1 shows the change that consumption patterns undergo alongside the acquisition of wealth. Taking into account the prognostics regarding the rising calorie consumption and the prospective change of consumption patterns, the explosiveness of the resource-controversy of nutrition becomes evident.

1.2 The material footprint of households

A variety of studies (e.g. Acosta-Fernández 2007, ETC/SCP 2011, Seppälä et al. 2011, Tukker et al. 2006) have shown that the food sector belongs, together with housing and mobility, to the three most relevant consumption components of modern societies in terms of natural resource use and other environmental impacts. Depending on the indicator used, the share of nutrition in the total resource use and environmental impacts of consumption ranges around one third to one fifth of the total impact of consumption. This evidence from mostly macro level studies has been confirmed by studies on micro level that have assessed the material footprint of the consumption of specific households.

Kotakorpi et al. (2008) report a share of appr. 15 % on average in a study on the material footprint of 27 different Finnish households. The 27 different households studied by Kotakorpi et al. (2008) consumed between 2.6 and 7.7 tonnes of material resources per person in a year for foodstuffs (see Fig. 1). The up to a factor 3 difference in the material footprints of the different households can be seen as a relatively small difference as the differences rise to a factor of 85 in the field of mobility.

Lettenmeier et al. (2011) studied 18 Finnish low-income single households. The nutrition of these households causes quite similar though slightly smaller material footprints (from 2.1 to 5.7 tonnes per person in a year) as the households studied by Kotakorpi et al. (2008). However, the relevance of nutrition in the total material footprint of the low-income households is higher as their total consumption is below average.

Mancini et al. (2011) assessed the material footprint of average diets in 13 European countries and the EU on the basis of data provided by Eurostat. These average material footprints range between 4.3 and 7.0 tonnes per person in a year. This is in the same magnitude as the material footprints of the specific households described above and shows that there are also notable differences between different countries. For countries outside Europe no comparable information on the material footprint of nutrition could be found so far.

In order to decrease resource consumption to a level in line with the planetary boundaries, the material footprint of household consumption should achieve a level of six to eight tonnes per capita in a year by 2050[1]. As the nutrition-related material footprint of

[1] A sustainable level for the material footprint of household consumption has been proposed by Lettenmeier et al. (2011) on the basis of the considerations of Bringezu (2009) on a sustainable level of Total Material Consumption for European economies. Total Material Consumption (TMC) means the total amount of life-cycle-wide abiotic and biotic resources consumption as well as soil erosion in agriculture and forestry of an economy. This means the same resources as the material footprint used in this paper (see section 2.1). TMC includes the domestic consumption and its global implications in terms of material flows but excludes export-related material flows as these are part of the TMC of the countries consuming the exported products. According to Bringezu (2009), a consumption of 6 tons of abiotic resources per each inhabitant of the world, 4 tons of biotic resources per capita for Europe and 0,2-0,3 tons of erosion could be considered a sustainable TMC. As a part of the TMC is used for public consumption (e.g. education, health care, public administration) and

households (see Fig. 1) and countries already may reach a level of 6-8 tonnes, also the material footprint of nutrition has to be reduced significantly by 2050 in order to ensure a decent lifestyle for all people in 2050 – despite of the fact that nutrition will always play a certain role in the resource use of households as it is the probably most basic need of human beings.

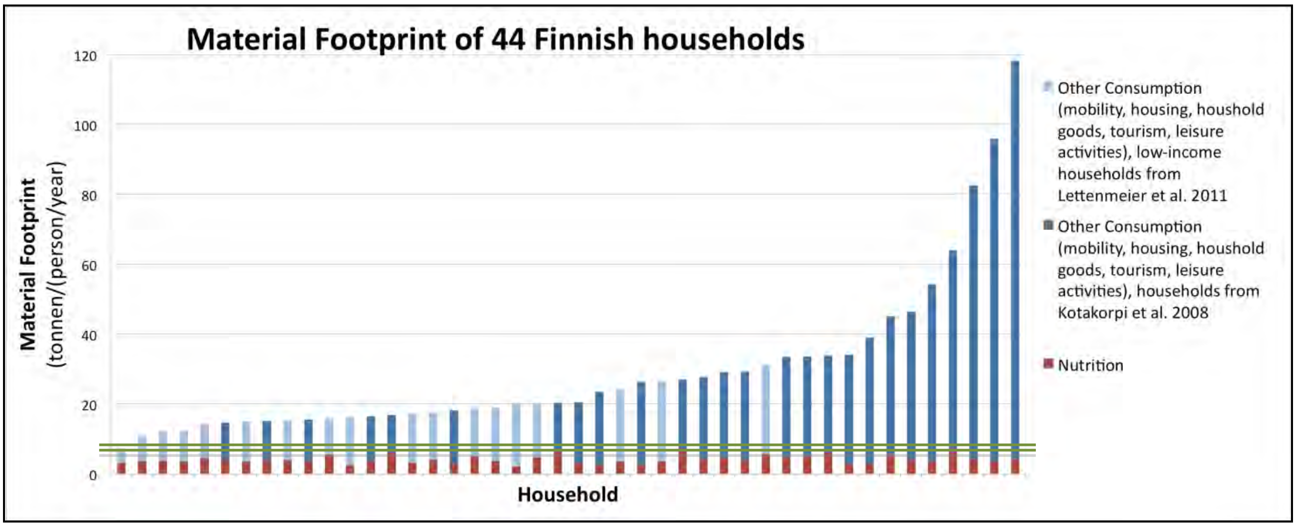

Figure 1. The share of nutrition in the material footprint of 44 different Finnish households and in relation to the sustainable material footprint of 6-8 tonnes (green lines).

1.3 The problem of food waste

The fact that 25-50% of foodstuffs are lost or discarded on their way from field to fork is increasingly critically observed by the public. The higher the economic growth of a country, the further the occurrence of food waste is pushed back within the value chain. In poorer countries, crop loss, storage and transport are the main reasons for food loss. In richer countries, the consumer is the one discarding most of the food (Gustavsson et al. 2011). Generally, it is possible to differentiate between loss of goods and destruction of goods. A loss of goods takes place, when sensitive raw ingredients have to be taken out of the manufacturing process due to technical issues, mistakes in handling or planning or spoilage. These have to be distinguished from by-products that arise during industrial food production (more definitions see European Commission 2010). Destruction of goods means the practice of destroying foodstuffs and meals that were meant to be consumed by humans, but are not called for, discarded due to oversized portions or rejected because of legal requirements. Both lost and destroyed food may partly be put to use in the feed industry or for generation of energy in biogas plants.

A closer look at the industry shows two contradictory facets that have to be considered when talking about loss and destruction of goods. On the one hand, food industry and retail constantly work on the reduction of the loss of goods. Focus is put on best-before or expiration date management, waste management and process enhancement on the individual value-added levels. On the other hand, in industry it is common practice to accept

companies' capital formation, Lettenmeier et al. (2011) estimate that households could probably consume 6-8 tons per capita per year. The role and share of public services in the context of sustainable resource use in total has not yet been addressed sufficiently. This is one reason for only defining a corridor of 6-8 tons instead of one exact value.

destruction of large amounts of foodstuffs for marketing reasons balancing between the availability of goods for an excellent product presentation with a high product range and depth and the amount of waste accompanied (Teitscheid 2012). For example, the rate of returns for bread and baked goods range from 10 (EHI 2011) to 20 % and for vegetables the number of destruction along the whole value chain is even higher.

Even though consumers consider themselves responsible for avoiding food waste, they also have a considerable part in the destruction of goods. Surveys conducted by Forsa (2011) and Cofresco (2011) confirm the trends that have also been observed in other industrial societies through long-term studies: Approximately 21 % of foodstuffs in German households are discarded, adding up to a value of nearly 25 billion Euros in expenses for food, or 80 kg of food per person in a year.

A Forsa poll initiated by the German Federal Ministry of Food Agriculture and Consumer Protection (BMELV) delivers initial findings on waste-behavior of German consumers: “About 84 % of Germans waste food because the expiration date has been reached, for many people a sign, that the goods have turned bad. 19 % also find exceedingly big packaging sizes to be their main reason. 16% of citizens throw away foodstuffs because they do not like the taste. And about one quarter states that they have bought too much in the first place. In the survey, 58 % declare that their household disposes of food on a regular basis. 69 % of the citizens have a bad conscience when discarding foodstuffs” (Lohmer 2011). The Cofresco study (2011) confirms these numbers. The research from Teitscheid et al. (2012) confirmed the causes of food waste in households finding that food is wasted because it has been forgotten, it has been stored wrong or it was not tasty.

Smil (2004) takes his examination of food waste to the next level and even takes into consideration the overnutrition, meaning the growing gap between food production and consumption. According to FAO’s food balance sheets all high-income countries now have available at retail level more than 3000 kcal of food per day per capita, with Europe leading the list. The entire continent averages nearly 3300 kcal/day and the EU mean was about 3500 kcal/day in the year 2000 (FAO 2002). The US rate is about 3600 kcal/day and the Canadian one about 3300 kcal/day. In contrast, aging population (metabolic requirements decline with age) and the increasingly sedentary way of urban life mean that the actual daily food requirements range mostly between 1500–2000 kcal/capita for adult females and 2000–2600 kcal/capita for adult males, and weighted means for entire populations are rarely above 2000 kcal/person.

This means that per capita gaps between average availability and actual consumption are now greater than 1000 kcal/day in every high-income country, with maxima approaching, or even surpassing, 1500 kcal/day. In order to account for inevitable food losses and to provide an adequate safety margin the average per capita food supply should be 30% above the needed mean of 2000 kcal/capita, averaging no more than about 2600 kcal/capita. The difference of 700 kcal/capita between this rate and the current EU mean could supply another 350 million people with the meaty and fatty diet that now prevails in affluent countries, or easily twice as many people consuming largely vegetarian but nutritionally adequate Asian diet Smil (2004).

1.4 Consumers longings

Consumers have started to search for sustainable lifestyles, even though it is not yet visible in actual consumption patterns. Surveys on the needs and desires of consumers in Germany and other European countries show the same picture: the consumption society shows its downsides. The possession of material goods is increasingly perceived as a burden, material consumption is no longer a guarantor for happiness, people feel threatened by the globalization and estranged from what they buy. Especially for foodstuffs values like homeland and naturalness move more and more into the foreground. Overall, the rich societies in Europe are on the road to a so called „Sehnsuchts-Konsumgesellschaft“ (consumer society of longing) (Lüdi/Hauser 2010).

The Gottlieb Duttweiler Institut in Zürich describes this development with the terms “reconnection” (to an idealized origin), “age of less” (less is more, restraint is no longer anti-pleasure, but relief) and “back to basics”. Applied to the food sector, this means: people yearn for regional and natural foodstuffs that they can prepare together with friends and consume in pleasant company. Unlike the politically motivated movement of restraint in the 1980’s, self-fulfilment is today’s main incentive (see Lüdi/Hauser 2010). Abstaining from material goods and moving towards enjoyment and aesthetics relieves people and helps them to do themselves something good. Today’s performance society, or meritocracy, with its high demands on daily life still forces people to compromise (see Falser/Dahlmann 2011), but desires show a different side (of society). This development is a chance for a change towards a sustainable lifestyle. It is yet unclear, in which way this development will affect consumer behaviour and supplies. During this process of transformation, consumers and producers need assistance in defining what makes a sustainable lifestyle.

For both producers and consumers, it is not easy to navigate in the prevailing jungle of different aspects and indicators of sustainability. In this paper, we use the material footprint, which means the consumption of natural resources during the whole value chain or life-cycle (see Lettenmeier et al. 2009), as the indicator for the ecological aspect of sustainability of nutrition.

2 Materials and methods used

2.1 Material footprint and resource efficiency potential analysis

The material footprint is a tool to measure and optimize the resource consumption of both products and their ingredients and the production processes along the whole value chain (Lettenmeier et al. 2009). It covers the whole life cycle of the products, from the extraction of raw materials to the processing industry, distribution, consumption, recycling, and disposal. In this paper the term material footprint is used as the sum of the consumption of abiotic and biotic resources plus the erosion in agriculture and forestry.

The material footprint is based on the MIPS concept (material input per unit of service, see Schmidt-Bleek 1993; 2009; Ritthoff et al. 2002). It provides a comprehensive and understandable tool to reduce different kind of present and future environmental challenges instead of or in addition to concentrating on specific problems. The material footprint thus serves as a tool to comprehensively direct activities to keep within “planet boundaries” as described e.g. by Rockström et al. (2009).

In this paper, the material footprint is used for comparing different foodstuffs and meals to each other on the basis of earlier studies. In addition, the material footprints of the following four different diets either existing or suggested are calculated in order to assess the resource efficiency potential and the level of sustainable resource use for nutrition:

- The average diet of a Finn in 2005 (directly from Lähteenoja et al. 2007).
- A diet developed from the average Finn 2005 based on the following assumptions: reduction of both amound and material-intensity of food by 10 % and dropping meat consumption from 79 to 14 kg per person in a year mainly by exchanging it with legumes like soya. These assumptions are based on experiences from households' material footprint studies (Kauppinen et al. 2008, Lähteenoja et al. 2008, Lettenmeier et al. 2011, Mancini et al. 2011), experiences from resource efficiency potential analyses (e.g. Rohn et al. 2010) and results of the food waste survey described in section 2.2.
- The Livewell UK 2020 diet proposed by Macdiarmid et al. (2011). The WWF UK published this report in order to provide guidance towards a more sustainable nutrition, to show how official diet recommendations should be developed to enable people to implement more sustainable diets and to discuss how to proceed to a 70 % reduction in carbon footprint of diets by 2050. It suggests a diet with a 25 % decrease in carbon footprint in 2020.
- The average Indian diet in 2007 on the basis of FAOSTAT (2011).

The material footprint values of foodstuffs, meals and diets calculated or presented here include only the natural resource consumption from raw-material extraction / production up to the point of sale, and thus do not include the material footprints consumers can influencing directly when travelling to the shop, storing and preparing meals at home and disposing off foodstuffs. This is in line with the studies of Kotakorpi et al. (2008) and Lettenmeier et al. (2011). Both studies allocate cooking and storing energy to housing, cooking and storing devices to household goods and shopping trips to mobility instead of nutrition in order to provide a comprehensive picture of the different consumption components. Cooking and storing devices cause relatively small material footprints when related to the material footprint of nutrition in general, the same is the case with disposal (Kotakorpi et al. 2008). A similar statement can be made for cooking and storing energy on the basis of the studies of Kotakorpi et al. (2008) and Lettenmeier et al. (2011). However, this cannot necessarily be generalized to any situation and any food product because both studies have been done in Finland and the material intensity of Finnish electricity is relatively low (appr. factor 3 to EU average and factor 5 to German electricity, see Kotakorpi et al. 2008, Salzer 2008 and Wiesen et al. 2010). The transport intensity of shopping can be even more relevant in terms of material footprint, expecially when cars are used for buying relatively small amounts of food (see Eberhard et al. 2010).

The resource efficiency potential assessment (REPA) compares the material footprint of a resource efficient option (e.g. product or diet) to that of the current status option (Rohn et al. 2012). Resource efficiency potentials can be identified either on micro level, regarding the value chain, or on macro level, addressing the potential to reduce resource consumption on a national level. REPA can be used for estimating the magnitude of a sustainable level of resource use for nutrition. Section 3.1 gives several examples of the resource potentials of diets. In section 4, the resource efficiency potential of nutrition is given as a suggestion for a sustainable material footprint level as a conclusion of the results given in section 3.

2.2 Identifying causes and effects of food waste

For action plans against food waste it is necessary to know the causes of loss or destruction of goods. The literature shows different reasons for food waste in the EU for specific areas: manufacturing, wholesale and retail, food service and restaurants (including hospitality industry, schools, hospitals) and households. Reasons for producing food waste are spread in the household sector and the food service sector and involve a range of issues including portion size, labelling, packaging, storage, awareness, preferences, planning and socio-economic factors. Households produce the largest fraction of EU food waste among the four sectors considered, at about 42 % of the total or an average of about 76 kg per capita. In the wholesale/retail and manufacturing sectors logistical and technical issues are most important (European Commission 2010).

For regional actions the Ministry for Environment in North Rhine-Westphalia, Germany has funded a study, which was developed in the working committee "the new valuation of food". The study includes an extensive literature research of food waste with international comparison. The survey is collecting data for the German state of North Rhine-Westphalia through qualitative research along the value chain to identify causes of food waste, approach within households to spot discarding food and leftover foodstuffs, valuation of food and possibilities for action and identification of food waste sources and ways of recycling.

The project analyses the link between causes and effects of "food waste" along the supply chain and identifies key objectives and stakeholders in a workshop with experts focusing on the development of options for political action to decrease food waste. In a second workshop with the participants of the working committee "the new valuation of food" options for action will be emphasized and their enforceability and acceptance will be requested.

To identify the causes and effects of food waste along the value chain (Fig. 2), the Institute for Sustainable Nutrition and Food Production (iSuN) at the University of Applied Sciences Münster used a qualitative approach examining the question: "What kind of food waste is occurring on which level of the value chain and for what reason?" Therefore 44 interviews with experts have been carried out inquiring food waste for the product groups: bread and bakery, vegetables, milk and milk products and meat and sausages along the value chain from the agriculture to retail.

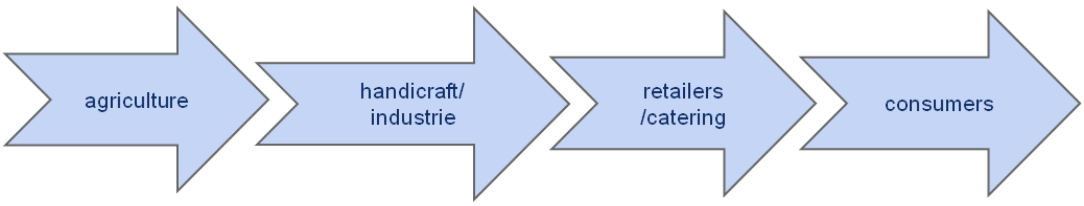

Figure 2. The supply chain of food

Qualitative content analysis is used for preparing evaluating and interpreting data within the team of researchers focusing on the development of actions to reduce food waste. This qualitative approach is looking at different products along the value chain but not studying the content of garbage bins to identify properly matching actions for the region. Thus, a vulnerability of the approach is that the statements of the interviews cannot be proved and are based on the information given by the respondents (Teitscheid et al. 2012).

3 Results

3.1 Resource efficiency potentials in diets

Material intensity data on numerous foodstuffs have been published, for instance, by Kauppinen et al. (2008), Lettenmeier et al. (2009) and Mancini et al. (2011). Foodstuffs can be compared to each other on the basis of their material intensity. Fig. 3 shows the material intensities (material footprint in kg of material resources per kg of the specific foodstuff) of different protein sources on the basis of Kauppinen et al. (2008). There are differences up to a factor of 10 depending on the source of protein. Beef and cheese are especially resource-intensive whereas soya requires relatively few resources when utilized directly as food. In general, meat tends to be resource-intensive but relatively high material footprints have been reported also e.g. for vegetables grown in greenhouses all year round (see Kauppinen et al. 2008, Eberhard et al. 2010).

Kotakorpi et al. (2008) have calculated the material footprints for a number of meals on the basis of material footprints of single foodstuffs (as shown in Fig. 3). Tab. 2 gives examples of the material intensities (material footprint in kg of material resources per kg of the specific meal) of meals. Also in these examples meals containing relatively high amounts of meat (e.g. mutton casserole, chilli con carne, double burger) tend to have high material footprints. There are still differences up to a factor of 8 between comparable meals (e.g. chicken casserole and mutton casserole) but other ingredients can reduce this difference (e.g. lasagne and vegetarian lasagne both contain pasta, tomato and cheese).

When the material footprints of single foodstuffs (like in Fig. 3) and meals (like in Tab. 2) are counted up to diets, Kotakorpi et al. (2008) report a level of 2.6 to 7.7 tonnes per capita per year with an average of 4.4 tonnes for the 27 different Finnish households studied. Five out of these 27 households had a vegetarian diet. Two of these vegetarian households are at the lower end of the range (3 tn.), two at average level (4.5 tn.) and one above average (5.6 tn.). Lettenmeier et al. (2011) report a level of 2.1 to 5.7 tonnes per capita per year with an average of 3.9 tonnes for 18 low-income single households. Only one of these households didn’t eat meat and was vegan. This household had a smaller material footprint for nutrition than all other households (2.1 tn.). Hence, a vegetarian lifestyle does not necessarily mean an especially low material footprint but the amounts of dairy products as well as fruits and vegetables consumed are also relevant.

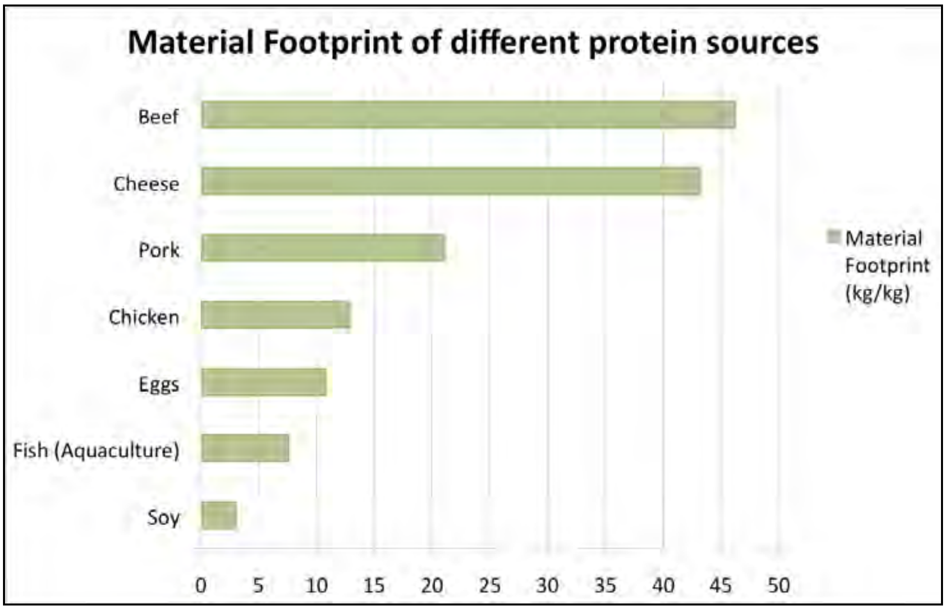

Figure 3. Material footprint of different foodstuffs used as protein source on the basis of Kauppinen et al. (2008).

Table 2.
Material footprint of different meals on the basis of Kotakorpi et al. (2008)

Meal	Material footprint (kg/kg)
Chicken casserole	7.5
Mutton casserole	59.2
Rainbow trout casserole	9.4
Chicken pasta	10.3
Chili con carne	24.8
Wild mushroom pasta	6.2
Patties of root vegetables	5.0
Meatballs	9.8
Lasagne	15.4
Vegetarian lasagne	9.6
Double burger	28.8
Veggie burger	6.5

Mancini et al. (2011) report a level of 4.3 (Poland) to 7.0 (Greece) tonnes per capita in a year for 18 foodstuffs consumed in 13 European countries and the EU. There are notable differences in the amount as well as in the material intensity of the foodstuffs consumed. The amounts vary from 460 (Germany) to 730 (Greece) kg/cap./a while the average material intensities vary from 8.4 (Poland) to 11.4 (Germany) kg/kg.

As the previous examples show, for the consideration of a sustainable material footprint level for nutrition, both the amount and the material intensity of the food consumed are relevant.

Fig 4. shows the material footprint of four different diets. The diet “Improved FIN 2005” was proposed and its material footprint calculated for this paper. Also the material footprints of “Livewell UK 2020” and “India 2007” were calculated for this paper.

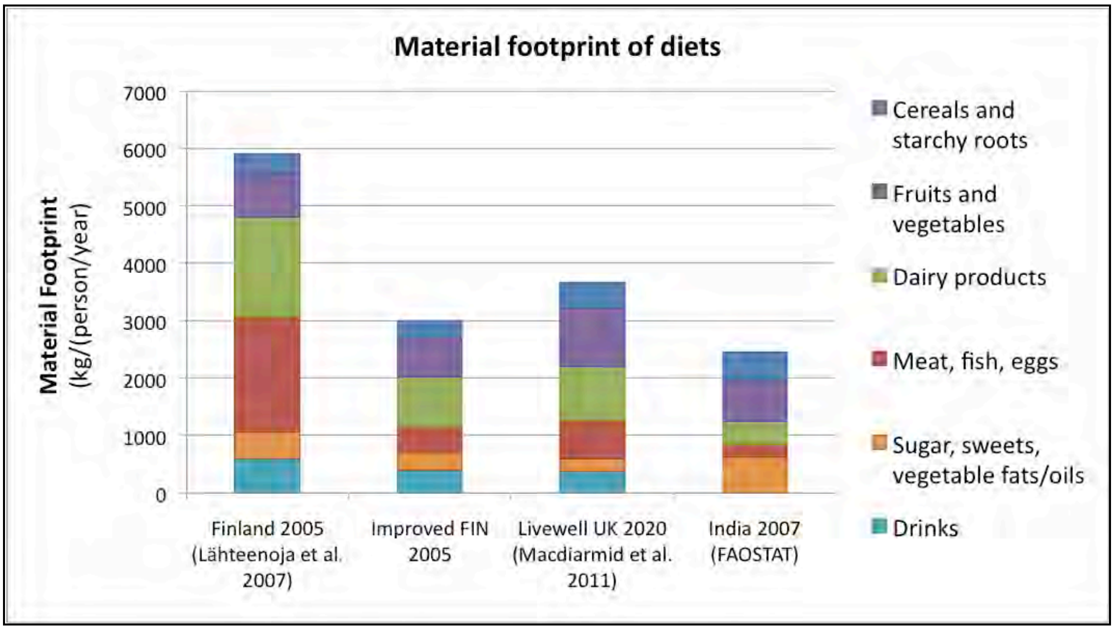

Figure 4. Material footprint of four different diets.

3.2 Resource efficiency in the food chain: potentials and limitations

Along the whole value chain for food, considerable possibilities exist for reducing the consumption of resources on different levels (see Teitscheid et al. 2012). Insufficient planning and a lack of communication often lead to food waste and losses that can be prevented through a consistent supply chain management.

However, there are boundaries that have to be considered: Food industry is the most efficient when natural raw materials used meet clearly defined standards with the lowest rate of deviations possible. To create such commodities, agriculture as the precursor to industrial food production aims to create the required standards through breeding and keeping conditions. So far, only few kinds of plants can be standardized like that and, accordingly, only few breeds of animals. In addition, this can result in a loss of biodiversity as a consequence of efficient food business.

A big challenge is to change the prevalent patterns of consumption and eating, as well as the dominant competition conditions. On the German market, for instance, a massive price competition prevails. Profit is mainly possible by concentration and by increasing business volume. Food is cheap and easily replaced, visual appearance drives consumption and waste behaviour, and consumers do not know and care much about the wastage of resources. Saturated markets create waste; foodstuffs in abundance are offered to the consumer at all times in a wide variety. Consumers orientate themselves strongly on the look of goods and only choose best products. All other goods are left over. Quality is whatever looks good, sensory quality fades into the background. All kinds of food are available at all times. Foodstuffs are cheap and replaceable with very little effort. Preparation has been handed over to the food industry. Consumers lack competences in the treatment of foodstuffs as well as in the judgment of food quality. Esteem has gotten lost – basic competencies lack.

The food production and distribution chain is governed by the rules of process optimization. Industry and retail set the standards and whatever does not fit into the machines or packaging is not harvested or used. Moreover, the volatile markets cause that agricultural commodities will not even be harvested if prices are too low, it is not profitable to pay workers to sort rotten fruit off a pallet and processes are not optimized to particularly reducing waste. At least food waste is kind of legitimized because it is an important source on so called secondary markets feed industry or biogas plants. This changed usage does not mean a direct loss of goods but a loss of value.

On the basis of the cause analysis above, two areas of action are identified for developing measures to reduce food waste and resource use. First, in order to reduce food waste and thus save resources the focus must be placed on the interface between the actors in the value chain and on actions across the whole chain. Even though the single steps of the value chain are nearly optimised, food waste is generated by a lack of coordination between these steps. Also complex relationships of cause and effect are found along the whole value chain and often occur and work on different levels. By recognising these relationships (e.g. quality standards for vegetables which are set by producers or retail) influence on the use of resources can be taken. Second, food waste is mainly systemic, which means market rules, the political framework and the behaviour of the actors cause. It is necessary to reformulate the political framework for the use of resources and to stimulate new consumption patterns by setting incentives, educating and internalizating external costs. A new esteem for Foodstuffs is indispensable (Teitscheid et al. 2012).

4 Conclusions

A sustainable material footprint for nutrition of 3 tonnes/cap./a would mean a share of 35-50% for nutrition in the total material footprint of sustainable households, which would be definitely more than at present (see Fig. 1). However, this can be justified, as nutrition is the most basic need of human beings so that the resource use for nutrition cannot be ever reduced.

On the basis of these findings a sustainable material footprint for nutrition of 3 tonnes/cap./a could be achieved by consuming 500 kg of foodstuffs of an average material intensity of 6 kg/kg. This means a factor 2 reduction in the average resource use for nutrition (Fig. 4). 500 kg of food consumption is at the lower end of European countries' consumption but still already achieved by some countries. 6 kg/kg is a relatively low average material intensity but e.g. cereals, bread, milk, eggs, domestic fruits, outdoor vegetables, soya and wild fish can be below 6 kg/kg already today (Kauppinen et al. 2008, Kaiser et al. 2012, Mancini et al. 2010). In addition, the waste prevention survey showed that there is still notable potential for decreasing resource use in the value chain.

We conclude with a short outlook on necessary steps and important research questions for a sustainable resource management in food production and consumption. A sustainable level of resource use for nutrition is achievable but requires a lot of efforts of all actors involved. Especially the following points should be taken into consideration:

- *Producers* and retailers have to increase resource efficiency by improving supply chain management and implementing technical, product and service innovations along the whole food chain.
- *Consumers* have to reinvent modern lifestyles and shift their diets towards smaller material footprints and better health.
- *Governments* have to promote sustainable nutrition habits by different interventions, e.g. by publishing less resource-intensive nutrition recommendations, setting waste

prevention targets and creating a resource-efficiency-orientated political and legal framework.

- Appreciation of foodstuffs is becoming a priority topic of *education* for sustainable development.

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