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Faculty of Natural Resources and Agricultural Sciences

Food Consumption in Rosendal

– the environmental support to diets in a “green” urban district

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Department of Urban and Rural Development
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Abstract

Food is a vital component to the survival of all life forms. Development of a global food system has increased food security yet produced greater environmental impacts, amplified by various threats to the global food system as well as a major use of natural resources. Since urban populations typically consume larger quantities of food with higher resource demands, the environmental support of food consumption in a “green” urban district is analyzed in this study. The purpose is to examine whether diets in Rosendal (Uppsala, Sweden) are more sustainable than the municipal average through an emergy synthesis. Architects were interviewed to determine if any explicit strategies were in place to promote sustainable food consumption in Rosendal. The results show that no strategies were in place, and food consumption in Rosendal is greater in both quantity and emergy when compared to the municipal average. Three alternative scenarios were developed to investigate whether food sourced locally, a vegetarian diet, or a locally sourced vegetarian diet could improve the sustainability of the current consumption pattern. It is found that the current diet sourced locally would produce the most sustainable and renewable scenario, yet the vegetarian options reduce overall emergy. Therefore, this study concludes that food consumption should be considered from a holistic perspective that integrates food production policies into urban planning, design and management to support growing foods locally and reductions in meat consumption.

Keywords: food consumption, emergy, environmental support, urban, green district, sustainability

Executive summary

Since we all need food for survival, we rely on the global food system to sustain our livelihoods. This reliance and food security could be affected due to various factors that may impact the global food system in a number of ways. These include climate change, natural resource constraints, environmental degradation, urbanization and trends in food consumption. Urban centers in particular are of concern since urban populations have been shown to consume not only more (empty) calories but also foods that have higher environmental impacts and require more environmental support. Therefore, the environmental support and sustainability of food consumption is important to examine for future sustainable urban food systems.

Rosendal, in Uppsala municipality, is one of twelve certified sustainable urban development projects in Sweden with high sustainability ambitions. Accordingly, the aim of this research is to analyze the sustainability of food consumption in a "green" urban district through an emergy synthesis to determine the environmental support (past and present resources) needed for food preparation and consumption in Rosendal. This is then compared to the municipal average, and three hypothetical scenarios are developed to determine where improvements could be made. In addition, architects were interviewed to determine whether there are any explicit strategies or measures to promote food consumption in a sustainable way. Data on food consumption for Rosendal's residents was collected using questionnaires that included a 24-hour recall and weekly estimations of food consumption.

The results from this study show that food consumption in Rosendal is not only greater in quantity, kg and Kcals, but also requires more environmental support (emergy) than the municipal average. The emergy of food consumption in Rosendal is 4.18E+15 where the output and UEVs generated from this study include urban life (labor) and waste. The hypothetical scenarios show that if the current diet in Rosendal is sourced locally, the sustainability and renewability of food consumption increases significantly. In addition, a shift to a vegetarian diet reduces the total emergy required to support food consumption in Rosendal. Furthermore, the architects indicate that there is no explicit strategy in place for food consumption. However, the inclusion of various fruit bushes and including opportunities to grow food show that food holds value in their definition in sustainability. From this, the study concludes that food production and consumption should be holistically considered in future urban policies, management, planning and design to support foods grown locally and reductions in meat consumption.

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1 Introduction

Food is essential to all life forms, and with that, it plays a key role in the health and survival of our planet. Not only is it important for the planet, it is also a central component to the survival and development of modern day humans. With the advent of agricultural production, food became a significant tie to our identity and cultural traditions as well as producing an industrialized commodity. While increased agricultural production and technological innovation has led to a global food system that contributes to greater food security, it has lead to more starvation and significant environmental impacts (Johansson, 2005). Consequently, what we eat and drink is a major determinant on the use and misuse of natural resources.

Natural resource constraints, climate change, urbanization, population and increases in the demand for food all play key roles when considering future food sustainability. Sustainable food production and consumption can be considered as one of the most important roles in food security and can be initiated at any level, arguably within food demand or consumption. Yet, many people know little about the impacts of their food consumption due to a lack of transparency (Vermueulen et al., 2012.) and disconnection from food production (Pretty, 2002; Feagan, 2007; Turner, 2011; O'Kane, 2012). If changes were made in dietary preference, specifically those in high-income countries characterized by high animal protein consumption such as Sweden, more food could be distributed throughout the world (WWF, 2016). Therefore, the consumer has one of the most influential roles in a truly sustainable food system, particularly relevant for urban areas.

In Sweden, more than 85% of the population lives in cities (UNFPA, 2014). Urban density and growth could strain its ability to sustain their agricultural need and food demand since 10% of agricultural land in Sweden has already been urbanized (Björklund et al., 1999). In combination, urban environments typically require more environmental support and imported resources (Huang & Hsu, 2003; Ascione et al., 2009). Moreover, urban populations typically consume foods that have higher environmental impacts and require more resources (Kearney, 2010; Tilman & Clark, 2014). Accordingly, it is important that city management and urban planning and design try to create more sustainable urban districts, such as Rosendal in Uppsala, Sweden.

Rosendal, as a new urban district, is one of twelve certified sustainable urban developments and is part of a forum that shares knowledge on sustainable urban development (Uppsala Kommun, 2015b; SGBC, 2016). The developers of Rosendal have high ambitions in their sustainability approach, and promote Rosendal as a *green* or sustainable district. Since Rosendal is promoted as a green district and large resource demands are behind food consumption, it is an interesting setting to investigate whether food consumption in a green district is more sustainable and requires less environmental support than the municipality.

Considering Rosendal is a new, urban district that is certified as a sustainable urban development has lead to the research questions that this study seeks to answer. The research questions are as follows:

1) What is the sustainability and environmental support (emergy) of food consumption in a green urban district like Rosendal?
    a. How does food consumption of Rosendal residents compare to the municipal average?
    b. How would the sustainability of food consumption in Rosendal change according to three hypothetical food systems?
2) Are there any explicit strategies or measures taken by the architects to influence food consumption in a sustainable way?

The main objective of the study is to determine the sustainability and environmental support for diets in Rosendal, using a holistic systems approach, in comparison to the municipal average and three hypothetical scenarios. Thus, this study aims to critically analyze food consumption, hypothetical scenarios and the sustainability ambitions of a green urban district such as Rosendal using emergy concepts and emergy synthesis as a method of environmental accounting. Emergy is a donor-based measure of direct and indirect resources or inputs (environmental work and global processes), both past and present, that create or maintain a product or service (Odum, 1996). This study is also part of a larger research project.

2 Background

Food (in)security, population growth, climate change and environmental degradation are some of the major concerns in the food production and consumption debate (Godfray et al., 2010). Already in the 18th century, Malthus showed concern for feeding a growing population, concluding that the population would grow faster than the supply of food (1798; cited in Johansson, 2005). While others were more optimistic in technological innovation, Malthus (1798) argued if food production met or exceeded demand then the population would increase creating famine and a subsequent push for higher agricultural yields. Thus, he envisaged a cyclical process with food production and consumption tied to increases in population and food demand (Malthus, 1798; Jiang 2014). From this Malthus developed the concept of a carrying capacity, concluding that the earth could only sustain a certain amount of humans for a definite time (George & Kini, 2016).

The idea of a carrying capacity is further developed in the framework of planetary boundaries and Brown (2010)'s concept of solar share, or share of consumed available solar energy. Rockström et al. (2009) propose planetary boundaries (PB) as a new approach to global sustainability that define and measure a safe operating space for humanity and development. PB are based on nine earth system processes that are affected directly and indirectly by human actions, agriculture and food production (Rockström et al., 2009; Steffen et al., 2015). Specifically, biogeochemical flows of nitrogen and phosphorus, essential fertilizers, are applied in intensive agriculture (Dawson & Hilton, 2011). Figure 1 shows that both biogeochemical flows in addition to biological integrity are in a dangerous zone of uncertainty (Steffen et al., 2015). The outcome of crossing these planetary boundaries is still uncertain, but the likelihood that destructive changes or shocks will disrupt the global flow of nutrients and the global food system is more probable.

The global food system is dependent on renewable, fixed but regenerative, and non-renewable, finite and exhaustible, resources from all over the world (Odum, 1996). Disruption to any of these resource supplies could stem from a number of global challenges, threats and pressures that would place the food system in a state

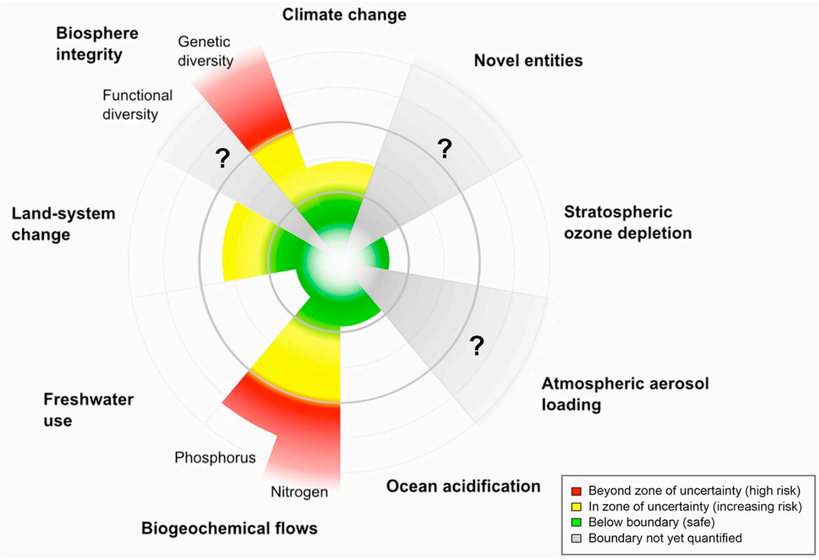


Figure 1. The current status of the control variables for seven of the nine planetary boundaries. Reprinted with permission from Steffen et al. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 736. Copyright © 2015, American Association for the Advancement of Science.

of crisis. This potential crisis coincides with non-renewable resource constraints, which are important to consider for future sustainable food systems. Similar to the idea of a carrying capacity or planetary boundaries, non-renewable resources have their limits, some of which have already peaked or are bound to at some point (Heinberg, 2010). While 60% water is considered renewable (FAO, 2011a), for example, it is becoming more scarce and degraded due to extensive extraction rates intensified by climate change (Bates et al., 2008). These factors, in addition to those mentioned in the introduction, constrain the ability of food system to adapt to meet growing and changing food demands.

The global food system (crisis)

Everyone needs food for survival and, accordingly, relies on and influences the global food system. The global food system is a network of organizations that work together in different processes that bring products and services to the market, fulfilling customers' demands (Jiang et al., 2014; see Christopher, 2005). Globalization of the food system occurred through global trade opportunities of food and agricultural inputs (e.g. fertilizers) made possible with technological development (i.e. refrigeration, transport), cheap fossil fuels and international trade agreements (Roberts, 2008; Conceição & Mendoza, 2009; Ackerman et al., 2014). Despite globalization and technological advancements, Conceição & Mendoza (2009) argue the global food system is in crisis for two main reasons: international trade of food and inputs and increasing environmental externalities from climate change and its effects on agricultural production. Figure 2 outlines other factors that could

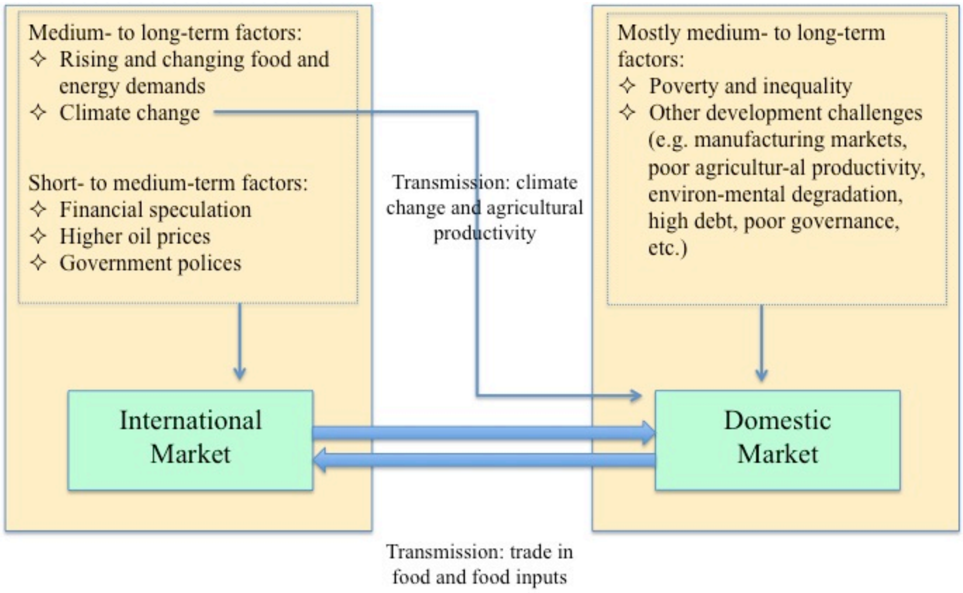


Figure 2. Anatomy of the global food crisis (edited from Conceição, & Mendoza, 2009).

impact the global food system, such as climate change and changing food and energy demands. These are important to consider since disruption to the global food system could impact any country, especially net importing countries like Sweden.

Both supply and demand impact the global food system, which are important to consider since food trade operates in a cyclical pattern (Jiang, 2014). On the demand side, population growth, urbanization, income distribution and increases, and changes in consumption patterns can influence the food system (Vermeulen et al., 2012). For example, population and diet-driven increases in global food demand drive the clearing of tropical forests, savannas and grasslands, threatening species extinction (Tilman & Clark, 2014). These challenges are aggregated by supply trends that are linked to climate change, institutional and societal processes, competition for natural resources (e.g. water and land), and interactions between food production and ecosystems services (Vermeulen et al., 2012). All of which influence the ability to address the current and future food gap[1].

The challenge to reduce the food gap and feed an expanding world is intensified by the environmental impacts of agriculture and the global food system. The food system is the leading cause of deforestation, degradation of water, land, soil, biodiversity loss, and accounts for 34-38% of land and 70% of all water consumption as well as 20-30% of anthropogenic greenhouse gas (GHG) emissions (UNEP, 2010; Garnett, 2014b; IPCC, 2014). These environmental impacts are derived from the use of fossil resources to power farms and in fertilizer (production), the

[1] A 70% gap in the amount of food produced today and the amount needed in 2050 (WRI, 2014).

number and management of ruminant livestock and flooded rice fields, and the conversion of habitats such as forest or peat land to fields and pastures. For example, intensive, large-scale monoculture operations require enormous land use and conversion as well as high volumes of chemical inputs that directly and indirectly impact wild species and habitat loss (Matson et al., 1997; German et al., 2011).

Furthermore, the energy-food nexus adds to the already declining or stagnant crop yields (e.g. grain production areas in east and southeast Asia, see Tilman et al., 2002). The food system's dependence on non-renewable resources, such as petroleum, is precarious and substantial (Pelletier et al., 2011; Sage, 2013), and the necessity to reduce GHG emissions could seriously constrain future food production. Moreover, oil is a finite resource and with peak oil less energy will be available for the production of food (Pfeiffer, 2003), which could further affect production yields and food security. Actions that simultaneously address peak oil and climate change could also impact agricultural production, such as a push for biomass or biofuel production.

Climate change is a major factor that can also influence food security and agriculture production. Vermeulen et al. (2012) reason there is sufficient evidence that climate change will affect not only food yields but also food quality and safety in addition to the reliability of its distribution. For example, places like Africa, South America and Asia are expected to have increased stress on natural resources, reduced agricultural productivity and quality, and increased drought related water and food shortages (IPCC, 2014). From history, extreme seasonal heat was not only detrimental to regional agricultural productivity and human welfare. International agricultural markets were also impacted when policy-makers intervened to secure domestic food supply (Battisti & Naylor, 2009). Consequently, food insecurity could be further perpetuated by environmental challenges in the food system, especially net importing countries. Therefore, changes in the climate and an increase of extreme weather and climate variability could be the one greatest challenge for a sustainable food system.

Solutions to these risks within the global food system vary from societal changes, technological development and improved management. Reducing food loss and waste on all levels of the food systems is one way to stretch current production. If food waste is halved, one-third to one-fourth of food between farm and fork, the food gap could be reduced by ~20% (WWF, 2016; from FOA, 2013). Another solution involves a shift to healthier, more sustainable diets. Studies suggest that if global meat consumption was ambitiously reduced by 2050, agricultural related GHG emissions could be reduced 55-72% (Stehfest et al., 2009; Popp et al., 2010; Tilman & Clark, 2014; Ranganathan et al., 2016), and even greater reductions if egg and dairy consumption decrease (Hedenus et al, 2014). Technocratic solutions include increased aquaculture production and crop yields on current agricultural lands (WRI, 2014). Better management of land, water and nutrient inputs would also benefit future global food production, for example a combination of conservation agriculture and agroforestry (Tilman et al., 2002; Hobbs et al., 2008; FAO, 2011a; Winterbottom et al., 2013; Mbow et al., 2014). It is evident that in order to close the food gap, a combination of these strategies from production to consumption is needed.

Since consumption (demand) impacts food production (supply), new models of production and consumption are necessary for a resilient, sustainable food system capable of absorbing and recovering from shocks yet supply enough food for a growing population (Macfadyen et al., 2015). Fresco (2009) describes a sustainable food system as one that is productive, responds to changes (i.e. in demand, costs, mechanization), resource and strict energy efficiencies, limits GHG emissions, is considered holistically and reduces vulnerability. Resources such as energy, land, labor and agrochemicals are important to future sustainable food systems, yet they will become scarcer, more expensive, and limited to reduce the environmental impact (ibid.). Even with technological innovations, food production capacity may be reaching its limits alongside an increasing world population and threats of climate change (Roberts, 2008). Therefore, the consumption side of the food systems becomes increasingly import to address.

Food consumption

> "Because people consume the products and services of nature, every person has an impact on the earth" (Johansson, 2005, p. 39).

In a global food system, there are many connections between food consumption and its impacts, environmental, social and economical, and pressures on future food supplies. Food consumption, as part of the food system, can alter the food system which can also influence food consumption. For example, supply patterns, including food availability, prices and marketing, have a strong influence on what people choose to consume (Kearney, 2010). These daily market interactions between producers and consumers give the food system its current form (Figure 3). While food consumption varies intra- and inter- nationally for a mixture of cultural, historic and climatic reasons, over the past fifty years trends in dietary changes emerged as incomes and urbanization increased globally (Tilman & Clark, 2014).

As nations continue to grow, urbanize and become wealthier, global trends are converging toward a 'Western-style' diet of high calorie, protein and animal product intake (Ranganathan et al, 2016). Trends in economic growth, especially of larger developing countries, not only increase food consumption but also alter eating behaviors (Gergens-Leenes et al., 2010). Typically, changes in consumption shift the fraction of nutritional energy from carbohydrates to fats and animal products (ibid.). In China, for example, as incomes increased the consumption of meat, pork in particular, fat and eggs increased while grain consumption decreased (Guo et al., 2000; Ma et al., 2006; Kearney, 2010). This is particularly evident in urban and high-income populations (Guo et al., 2000; Ma et al., 2006) throughout the world. Global trends thus include increased consumption of per capita meat and milk (WRI, 2014; Ranganathan et al., 2016), fats, total calories and empty calories with decreased consumption of cereal products (Tilman & Clark, 2014).

Figure 3. Schematic representation of the choices we make in food consumption affect the globe as well as global trends affect the choices made in food consumption (Photo: Tarnovska, 2016).

Not only has the current global dietary shift toward calorie-dense foods led to higher rates of obesity and diet-related non-communicable diseases, it has also increased environmental impacts, GHG emissions and the use of natural resources, (e.g. clearing of land and the use of more water and nitrogen) (Tilman & Clark, 2014; McLaughlin & Kinzelbach, 2015). For example, in Taiwan Lin (2015) found that the resources used for food consumption are much greater than the natural environment, or renewable resources, can provide. This finding was more significant for urban areas (ibid.). Moreover, food consumption has been found to account for 48-70% of household impacts on water and land use (Ivanova et al., 2015). As discussed in the previous section, this places a huge strain on (critical) water and land resources worldwide.

If Western-style food consumption trends continue until the year 2050, Tilman and Clark (2014) estimate food production emissions will increase 80%. Likewise, McLaughlin and Kinzelbach (2015) conclude that if demands for high calorie meat-based diets continue, in addition to other poor management and production tactics, there may not be enough resources (land and water) to feed future populations. Furthermore, diet choice is a major determinant in the energy used in the food system (Pelletier et al., 2011). Using Swedish conditions, Carlsson-Kanyama et al. (2005) found changes to green consumption patterns could lower indirect energy by up to 30% if expenditure levels remained stable. Accordingly, it is important to focus on a sustainable food system with an emphasis on sustainable food consumption as well as production practices.

Garnett (2014a) addresses the importance of what we eat, stating that “achieving sustainable, health enhancing food systems requires action to improve what and how much we eat, as much as how we produce it" (p. 18). Weber and Matthews (2008) argue that switching one-day's red meat and dairy calories with a week of consuming vegetables, fish, eggs or chicken more effectively reduced GHG emissions than buying local for a week. Similarly, Ranganathan et al. (2016) show that shifts to low beef and other animal product consumption by high meat and dairy consuming countries could result in fewer GHG emissions. For example, Scarborough et al. (2014) show that GHG emissions from meat-eaters are twice as high as vegan-based diets, and reductions in meat consumption can reduce dietary GHG emissions. In addition, large-scale diet shifts toward Mediterranean, pescetarian, and vegetarian diets were found to potentially reduce land clearing (resource use) and global agricultural emissions by 2050 (Tilman & Clark, 2014).

Many agree that diet changes to fewer animal and more plant-based food reduce the impact and environmental support of food consumption. Thus, to become sustainable, the food system needs to change and/or adapt which includes diets and consumer habits (Fresco, 2009; Garnett, 2014a). However, transferring environmental responsibility to personal consumption is a significant challenge, and institutions of higher education's efforts to impact attitudes and practices related to sustainable consumption have largely been ineffective (Schoolman et al., 2014).

From a consumer perspective, the (negative) effects of food consumption are hard to identify in part due to the loss of transparency and experience with the food (production) system (Pretty, 2002; Feagan, 2007; Turner, 2011; O'Kane, 2012). Yet, "many of the trends within the food system are formed by the choices we make about what food to consume" (WWF, 2016, p. 96). By encouraging consumers to eat healthy diets with moderate animal protein and within the NHS (2016) recommendation of 2000 to 2500 calories per day for women and men, respectively, the availability of food could be enhanced and environmental impacts and resource support of agriculture lowered (WWF, 2016). Other targeted efforts that could be pursued to enhance food security include waste reductions associated with the production and consumption of our most resource-intensive foods, meat and dairy (ibid.). All of these changes could free up resources that have the potential to sustainably feed the world, especially since the production of animal foods generally has more impact on and resource demand from the planet than plant-based foods. Accordingly, cutting meat and dairy consumption, beef in particular, in wealthier and high meet consumer nations is an important component for realizing a sustainable food future (Tom et al., 2015).

Urban trends

With urbanization increasing to 66% of the global population by 2050 (UNFPA, 2016), challenges in sustainable development become more concentrated in cities

(UN, 2014). Urban centers are a crucial focus point since they typically have higher environmental impacts, both directly and indirectly in their resource support system. The world's cities account for 60-80% of energy consumption yet occupy only 2% of the all land (FAO, 2016). Therefore, one of the major challenges becomes sustaining food production to fulfill the demand of an urban population (Angotti, 2015) that is removed from the traditions of food production and its environmental impacts (Pretty, 2002; Feagan, 2007; Turner, 2011; O'Kane, 2012). Imaginably this obscures how our food consumption influences environmental impacts on ecosystems in addition to monetary systems (Donati et al., 2016).

Not only is food consumption, in general, greater than their rural counterparts (Kearney, 2010), Schneider et al. (2011) show that urban areas will acquire 3% of all current crop land areas (roughly ~38.52 million ha[2]) by 2030. Furthermore, food supplies are transported into urban areas, which is important for their environmental impact and resource support (Deelstra & Girardet, 2000), a key issue for this context. One way to deal with such impacts is through urban and peri-urban agriculture. Urban agriculture not only reduces food miles (the distance food travels), it contributes to the sustainability of cities socially, economically and environmentally (ibid.). It is also an avenue to generate environmental awareness and educate on sustainability as well as the role consumers have in the global food system through training, workshops, seminars, etc. (ibid.). In addition, Bergquist (2010) shows the potential sustainability benefits of urban agriculture, such as better use of local renewable resources, recycling urban waste and decreased reliance on imported, non-renewable resources.

Previous studies recognize the significance of the imported material and energy that supports urbanization trends, and express concern about their environmental and social consequences (Obernosterer et al., 1998; Barles, 2010; Weisz & Steinberger, 2010; Ascione et al., 2009; Ascione et al., 2011). Hence, cities are considered consumer systems that cannot self-regulate without stable links with external systems from which they draw energy, materials and food and release their waste (Huang & Hsu, 2003). The inability to create institutions that encourage efficient management of natural and environmental resources, create technological adaptations to the challenges in the economy and environment, and promote human capital can be seen as one of the main causes of unsustainable cities (Dentinho et al., 2014).

Sweden

Disruption to the food system will impact high import countries, such as Sweden, to a larger degree (Conceição & Mendoza, 2009) partly because agricultural

[2] Mean of the 5 scenarios modeled by Schneider et al. (2011).

land area has been on the decline since the 1950s and 60s (Björklund et al., 1999; Swedish Statistics, 2016). As part of the global food market, changes in climate and supply and demand in other parts of the world will affect Swedish agriculture, seen in Figure 4, and food availability (Johansson, 2008; Fogelfors et al., 2009). Deutsch and Folke (2005) show that the Swedish food system is substantially dependent on foreign ecosystems and imports for food production and consumption.[3] For example, significant amounts of imported crop inputs are used in the domestic production of feed mixtures needed to maintain Sweden's consumption of meat, eggs and dairy (ibid.). Lagerberg Fogelberg (2013) demonstrates the possibility to reduce impacts and increase overall efficiency and renewability in the production of Swedish meat and dairy products by sourcing feed inputs locally.

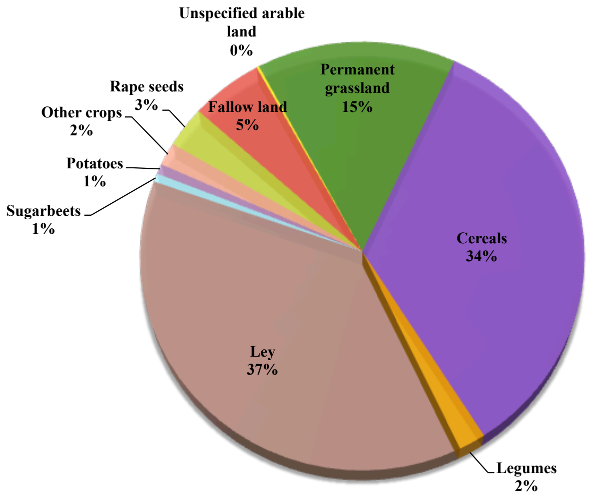


Figure 4. Agricultural land use in Sweden (Swedish Statistics, 2016)

From the period of 1960 to 1994, domestic food consumption's reliance on agricultural areas outside of Sweden increased to 35% and animal production consumption accounted for 80% of all agricultural consumption (Deutsch & Folke, 2005). While Sweden's domestic agricultural land continues to decrease during this period, yields increased through agricultural intensification, farm specialization, greater reliance on fossil fuel-based inputs and human-made capital (i.e. technology) (ibid.). Out of the total fossil fuel consumption in Sweden, 15% is used by the Swedish food system whereas less than 15% of its resource use is local and renewable (Johansson, 2000; Fogelfors, 2009). While domestically Sweden may not contribute to a significant amount of direct CO_2 equivalent emissions related to agricultural land cover change, imports associated with their food system cause international land cover changes (Johansson, 2005).

In national study, Johansson (2005) shows that the environmental support needed for food consumption is 40 times larger than the agricultural area and 3.6 times larger than all land area in Sweden, most of which was from imported resources. Russo et al. (2014) looked at the urban metabolism in Uppsala, Sweden and found the entire municipality required nearly as much resource support as national food

[3] Imports are largely from other European countries, Asia and South America.

consumption. They identified that the main flows strongly rely on external driving forces to maintain city structure and functions, and food consumes 10% of all the environmental support to the municipality (ibid.).

Currently, food consumption in Sweden is increasingly resource demanding and dependent on agricultural land abroad. Approximately 30% of food consumption in Sweden is dependent on external land (Johansson, 2005; Fogelfors et al., 2009). Furthermore, the consumption patterns in Sweden are similar to the global trends. Saturated fat consumption is approximately 12.6% of an adult's caloric intake (WHO, 2013; from FAO 2007). Accordingly, it is estimated that 49-53% of the adult Swedish population is overweight and adulthood obesity it projected to increase to 26% and 22% of men and women, respectively, by 2030 (WHO, 2013).

Uppsala and Rosendal

Uppsala municipality, in Sweden, is home to over 200,000 people (Uppsala Kommun, 2016) and holds the nations fourth largest city. As with many other urban populations, Uppsala is growing at a rapid rate. The population is projected to reach 250,000 by 2030 and 300,000 by 2050 (ibid.). The vision for Uppsala 2050, according to the master plan (ÖP, 2010), is to develop social appeal and traction, a municipality for all, and, most important for this paper, a city that is able to stay within the planetary ecological limits (Uppsala Kommun, 2015a). To address the demands of the growing city in a sustainable way, new urban districts need to be developed in Uppsala that are capable of fulfilling the vision for 2050.

Rosendal, located in the southern region of Uppsala, is a newly developing district with such claims, approximately 2.5 kilometers from the center (Figure 5). Uppsala's comprehensive plan indicates that this area was suitable for development already in 1985. Because the city needs changed, the early plans were improved to support the increased housing demand and needs of Uppsala University. In 2010, a detailed plan was developed for the southern region, the window of attention for this study. A more detailed plan was developed in 2015 (Uppsala Kommun, 2015a).

As a new district in Uppsala, Rosendal is promoted as a green, or sustainable, district. 'Small-scale' and 'diversity' are keywords that describe the development of Rosendal (Uppsala Kommun, 2015b). Accordingly, Rosendal is designed to be a mixed, multifunctional environment that promotes social, environmental and economic sustainability, and interaction with the local environment (e.g. neighbors, shops, etc.) (ibid.). The vision for Rosendal is proximity to encourage residents to work in the area so that it is possible for them to walk to work (ibid.). Hence, the district is to become a mixture of residential areas, offices, commercial

Figure 5. Schematic representation of the Rosendal area located in Uppsala municipality found in Sweden (DigitalOfficePro, 2015; Rosendal Fastigheter, 2016).

sites, university-related facilities, and schools in the vicinity of parks, natural areas, and more (ibid.).

In Rosendal, the goal for multifunctional areas is to achieve as many synergies as possible. This includes public spaces and buildings that contribute to ecological diversity (Uppsala Kommun, 2015a). Rosendal's location harmonizes with another goal, closeness to nature (Uppsala Kommun, 2015b), as it is situated adjacent to the city forest. Further goals for Rosendal include safety and comfort for all ages, diversity and multifunctional in all aspects, and resource-efficiency (ibid).

In addition, Rosendal is one of twelve urban construction projects in Sweden to become a certified sustainable urban development. It is also part of CityLab, a forum for sharing knowledge on sustainable urban development organized by the Swedish Green Building Council (Uppsala Kommun, 2015b; SGBC, 2016). The developer Rosendal Fastigheter's (Rosendal Real Estate), recently associated with SGBC, has high ambitions for their sustainable approach. For example, some of their projects in Rosendal (i.e. Smaragden, E in Fig. 6) include berry bushes, fruit trees and sedum roofs to benefit biodiversity, improve building insulation, and delay storm water. Aspirations to reduce other ecological impacts include generous bike parking and paths, access to public transportation, and limited car parking. To promote social sustainability, some buildings have access to a large public roof terrace, restaurants and sport courts on the ground floor (Rosendal Fastigheter, 2016). Therefore, Rosendal, promoted as a green district with high sustainability aspirations, is an interesting setting to examine food consumption.

3 Theoretical Framework

Sustainable lifestyles are embedded in complex systems where individual factors and the physical and social environment play a crucial role in their acceptance (Vlasov, 2015).

Systems approach and self-organization

The global food system yields a variety of products and requires a lot of inputs to deliver food commodities from farm to fork. If agricultural processes are considered alone then the integration of large resource inputs used in processing, transportation, distribution, and marketing are omitted (Johansson et al., 2000) as well as the processes included in recycling food waste to biofuels. The term "food system" is often used freely or thought of in a linear fashion, and the whole system and its processes are not always tied to systems theory (Sobal et al., 1998). In this study, the food system is considered from a holistic and broad agroecological perspective that encompasses all ecological, economic and social dimensions (Francis et al., 2003) with respect to all the contributions of man and nature that support food consumption (Johansson, 2005).

Since food production varies by climate and farming practices, an apple produced in Sweden and an apple produced in Chile will have different environmental impacts when consumed in Sweden because they are produced and consumed in different systems (Johansson, 2005). Even similar products with the same origin, market price and consumers may imply different production practices, and consequently different impacts. Because food products of different types are produced in different yet interconnected systems, the problems within these systems are connected. As in any complex system, the global food system is a diverse, dynamic and complex web of interlinking and interacting subsystems (Vermeulen, et al., 2012). Changes or perturbations can occur in response to natural forces, economics, technological innovation, demographics, entrepreneurship, and food preferences (Hueston & McLeod, 2012), which could provide opportunities and/or challenges for the global food system (Fresco, 2009). The food system relies on all its interconnected subsystems; and for future sustainability, different scales and their linkages need to be considered. Thus, a holistic systems approach is needed when considering the impacts of food consumption since it can detect different ways to deliver the same output, and assess what alternatives may be more efficient, renewable, etc.

The notion that system components interact through one or several processes and are dependent on one another is a key concept in systems thinking (Francis et al., 2003). From a holistic systems approach, when a system's components interact the whole is more than the sum of its parts (Odum, 1994; Meadows, 2008; Mele et al., 2010). Accordingly, systems theory is a theoretical perspective that considers the system as a whole, embedded within a large system, and the processes or interactions (e.g. feedbacks) occurring within the system and connections to other systems at multiple scales, versus looking at each process or component separately (Mele et al., 2010). Systems theory, according to Capra (2005), recognizes the complexity of systems and the concept of self-organization. The idea of self-organization, while it stems from natural sciences, can be applied to the system of human society, not only its environment, since humans cannot be separated from the system (Kay, 1999). They cannot be considered separately since we consume food and the energy from food is utilized or stored. Waste and labor are then an outcome of food consumption.

In self-organization, different levels or a hierarchy of energy, materials and information are generated by the work of nature and society. While the concept of hierarchies is often criticized in social sciences, the basis of self-organization suggests that hierarchies enhance system performance by producing structures and patterns that reinforce lower level processes (Odum, 1996). For example, zooplankton's energy feeds the fish whereas the energy of the fish feeds the bear. While acting as a predator, bears act as a controlling function that regulates the fish population to remain within the carrying capacity of the ecosystem as a whole. Each helps control the quantity, quality and distribution of one another.

Accordingly, there is a division of labor where each level does something that reinforces the processes of the other (Odum & Odum, 2001). Therefore, all energy transformations in the geobiosphere can be organized as an ordered series that forms a hierarchy (see Table 1) and when viewed wholly are interconnected webs of energy flows (Brown & Ulgiati, 2004a). As considered in systems theory, there is no real production or consumption because most processes have both, where a range of inputs are transformed into something new. Thus, it is better referred to as transformation.

Maximum (em)power principle and emergy

In 1886, Boltzmann pointed out that available energy (exergy) is a fundamental contention to the evolution of the organic world (Lotka, 1922). Accordingly, the principle positions the advantage to the organisms whose energy-capturing capabilities efficiently direct available energy into channels (for maximum power) that support the preservation of the species (ibid.). The *maximum power principle* states that systems self-organize by developing the most useful work from incoming energy, reinforcing productive processes and overcoming limitations via system organization and re-organization (Brown & Ulgiati, 1999). Autocatalytic feedback is developed which is important to maximize power and process more useful energy (Odum, 1996). This principle is a fundamental theoretical concept in systems ecology and emergy.

While tracing energy flows in ecosystems and considering the diverse biosphere processes, H.T. Odum developed the concepts and theories behind energy quality and emergy (Brown & Ulgiati, 2004b). Emergy, or energy memory, traces the previously used available energy that is a property of the smaller amount of available energy used in the transformed product (Odum, 1996). Motivated by his desire to understand the biosphere on the small to large scale, Odum took a different approach to defining energy with the aim to quantitatively define energy quality and understand the net yield of many energy sources. Energy quality reflects the different work potential of different energy sources, such as sunlight, and the transformation of the sun's energy into other sources of energy (e.g. a tree or oil). Thus, energy quality is measured by the energy used in the transformation of one type of energy to another (Brown & Ulgiati, 2004b), including historical or embodied energy. Accordingly, energy quality is represented by the amount of embodied energy or emergy required to produce a product or service (Odum, 1996).

Most forms of energy are derived from the sun, the earth's deep heat and tidal energy. Therefore, many of the natural processes and ecosystem services are byproducts of these three forms of energy. Since biosphere processes and global emergy flows are so varied and heat is not the only output, Odum thought a common denominator was necessary to evaluate the different forms of energy quality from input to output. In order to compare the energy quality, Odum reasoned to convert various energy forms into their solar energy equivalent, solar emjoules or emergy (seJ), since it is the largest, yet most dispersed, energy input to the earth (Brown & Ulgiati, 2004a). To convert global emergy flows, transformities were developed to equate the emergy of most products and processes of the biosphere (Table 1). A transformity is the emergy of one type required to make a unit of energy of another type (Odum, 1996), which later, is referred to as the Unit Emergy Value (UEV). As a starting point for transformity calculations, the three prima-

Table 1. *Typical transformities (Odum, 1996).*

Item	Solar Emcalories per calorie*
Sunlight energy	1
Wind Energy	1,500
Organic matter, wood, soil	4,400
Potential of elevated rainwater	10,000
Chemical energy of rainwater	18,000
Mechanical energy	20,000
Large river energy	40,000
Fossil fuels	50,000
Foods	100,000
Electric Power	170,000
Protein foods	1,000,000
Human services	100,000,000
Information	1×10^{11}
Species information	1×10^{15}

*Calories of solar energy previously transformed directly and indirectly to produce one calorie of energy of the type listed.

ry forms of energy, or exergy, are combined in a global emergy baseline (GEB), or a uniform solar equivalent exergy reference (Brown & Ulgiati, 2016).

The fundamentals of emergy are based on systems ecology principles and the laws of thermodynamics with recognition of the biophysical limits to conversion processes. Inspired by the maximum power principle, Odum (1996) proposed the maximum *empower* principle. The maximum empower principle states that systems at all scales prevail first through system organization to develop the most useful work from inflowing *emergy* sources reinforced by productive processes and overcoming limitations, and second through increasing the efficiency of useful work (Odum, 1996, pp. 19-21). A third contribution of the maximum empower principle is useful work to larger scale systems. Accordingly, self-organizing systems generate autocatalytic storages to maximize useful power transformations and disperse energy faster to maximize the rate of entropy production through developing autocatalytic dissipative structures (ibid.).

Since emergy considers all systems as networks of energy flow (Zhao, Li & Li, 2005) and emergy is always increasing, systems that do not use resources efficiently (waste energy) without increasing the inflow of emergy are not considered reinforcing and cannot compete with systems that use emergy inputs in self-reinforcing ways (Brown et al., 2000). In addition, a high degree of dependence on other systems implies weak competitive capacity (long-term sustainability and self-sufficiency) because resource availability and maintenance control does not belong to the system (Pulselli et al., 2008). Therefore, a sustainable system should self-organize to efficiently make use of resources while increase inflow of emergy.

4 Methods

The nature of complex systems supports the use of an interdisciplinary approach. According to Allen et al. (1991), an integrated interdisciplinary approach is vital to adequately addressing complexities of the interactions in the total food system. Therefore, qualitative and quantitative methods are combined to assess food consumption of the inhabitants in Rosendal.

Questionnaires

Questionnaires were selected to collect qualitative and quantitative data on individual food consumption. Questionnaires were chosen since the data can be used to make larger societal decisions (Slattery et al., 2011), and its frequency in dietary assessments. In addition, questionnaires permit flexible distribution and can be used in person. Individual consumption was chosen since economic, social and behavioral factors that influence household food distribution vary on an individual level (FAO/WHO, 2016). Likewise, individual consumption data better informs agricultural and food policies and programs on all levels, subnational to global (ibid.). In the development of the questionnaire, all questions were guided by Foddy (1994) to avoid questions not in chronological order and wrongly primed the participants. The questionnaires included an introduction to the study, demographics, general consumption and lifestyle section, and a section on food consumption. The food consumption section contained two different dietary assessments, a 24-hour recall and a weekly estimation of food consumption (see Appendix 1). The dietary assessments are the focus here since the general consumption questions, apart from question one, were outside the purpose of this study.

24-hour recall

As an open-ended method, 24-hour recall is applicable to various cultural settings with international comparability (e.g. Europe, U.S. and Australia) (Savy et al., 2006), and as such is suitable for the Swedish context. The 24-hour recall allows respondents to freely recall what was consumed a day before and is considered an effective way to elicit dietary information (Savy et al., 2006). In addition, it is considered a suitable method to obtain population means and the distribution of actual intake (Brussard et al., 2002), the study's purpose and reason for its use.

An implicit assumption of a 24-hour recall is that a single day is somewhat representative of a usual pattern of intake (Block, 1982). While a single 24-hour recall does not represent the usual individual intake, it adequately characterizes the average intake of a group or population (Biró et al., 2002). Brussard et al. (2002) recommend conducting multiple 24-hour recalls over a span of a year; however, time constraints limited the survey to only one 24-hour recall with 34 participants. Since the purpose of the 24-hour recall for this study is to obtain the mean food consumption of inhabitants in Rosendal, collecting single individual data in the 24-hour recall should not hinder the validity of the results.

To help improve the accuracy of food quantification and reduce the likelihood of underreporting, a major drawback of 24-hour recall (Macdiarmid & Blundell, 1998; e.g. Champagne et al, 2002), participants were given a visual aid to improve and describe their recalled food intake (see Appendix 2). Several studies report the benefits of including photographs or using a food atlas to help respondents assess portion sizes (Nelson et al., 1996; Turconi et al., 2005; Bouchoucha et al., 2016) and reduce respondent burden (Lazarte et al., 2012). Improvements have been found in food intake, (Bernal-Orozco et al., 2013; Hernández et al., 2015) some of which highly correlate to actual food intake (Bouchoucha et al., 2016) when photographs depict a higher range of portion sizes (Nelson et al., 1996). Therefore, the food atlas used includes five to eight portion sizes and corresponding weights for 12 culturally appropriate foods chosen from the national portions guide Livsmedelsverket (2009). These include (1) soup and liquids, (2) bread, (3) butter or bread topping, (4) cheese, (5) fruit, (6) grains and rice, (7) salad, (8) cooked vegetables, (9) potatoes, (10) pasta, (11) salmon, and (12) beef.

Estimation of average weekly food consumption

To mitigate limitations and act as a calibrator, the participants were also asked to estimate their average or typical weekly food consumption of 14 different food categories (Table 2 in Appendix 1). The food categories are cereals and derived, starchy vegetables, vegetables, fruits and berries, fish and seafood, dairy products, eggs, oils and fats, sweets, stimulants, and alcoholic and non-alcoholic beverages. These categories largely follow the categories used in the national study by Johansson (2005) and USDA (2003), which are comparable to Russo et al. (2014). Although, this method is not well referenced, it is believed to be an appropriate method to use since it is similar to and an adaptation of a food frequency questionnaire (FFQ). The main difference is that the food frequency is aggregated into

14 food categories versus a detailed list of food items. In addition, the typical recall time for a FFQ is a month, whereas it is reduced to a week in this study. Both the aggregation of food and reduction in the time frame were done for the aim of reducing participant frustration and the duration of the questionnaire.

Grouping foods into a single question, i.e. aggregating them into food categories, as done here, raises assumptions when calculating the relative frequency of intake and portion size for individual food items (Cade et al., 2002). However, the purpose is not to separate the food categories into their individual food items, hence assumptions did not have to be made in this regard. However, assumptions were made in the participants' ability to accurately estimate their food consumption using food categories in the frame of a week.

Following the weekly estimation, additional questions were included that pertain to the percentage of organic and local (from Sweden) foods consumed were included. The term local is often used to position the consumer in relation to the produce (Joosse, 2014). Therefore, local was defined as Sweden and the frame for participants to consider their food consumption since the national study referred to local renewable inputs as products from Sweden (Johansson, 2005). Subsequent questions were included to gather more quantitative data in regards to food waste, time spent cooking, money spent on food and frequency of eating out. The ability to add such questions is a benefit of the flexibility in questionnaire design and the data collected was used in emergy synthesis.

Procedure

After a trial of the questionnaire, contact was made with the residents in Rosendal. Local residents were selected at random based on their willingness to partake in the study. Contact was made with the residents by approaching them in Rosendal. First, it was important to determine whether the respondent knew English and subsequently whether they lived in Rosendal. Next, the potential participants were introduced to the study, followed by the potential duration of the questionnaire (~20 minutes), and then asked for their participation.

In total, 34 residents currently living in Rosendal agreed to participate in the questionnaire, but one was discarded to incomplete answers. Therefore, 33 residents were included in the results, 17 women and 16 men from the age range of 19 to 75 with a mean age of 33 (see Table 2). Figure 6 outlines the number of participants for each apartment building currently finished in Rosendal. As seen in the figure, there is fairly equal distribution of participants for the different areas in Rosendal. The least surveyed area is in building A, student housing. Still, the region and youth are adequately represented.

For those who agreed to participate, in person questionnaires were conducted either outside, in the entrance to apartment buildings or apartments. The partici-

-pants were then handed the pen and paper so they could be a part of the study. The materials used in this study, as mentioned above, consisted of the questionnaire and food atlas. Prior to starting, the participants were reminded of the purpose, examining food consumption in Rosendal considering it is promoted as a green, sustainable district.

Table 2. *Demographics of the participants included in this study.*

Age Range	Male	Male Percent	Female	Female Percent	Total
18-25	7	21%	8	24%	45%
26-35	2	6%	6	18%	24%
36-45	2	6%	3	9%	15%
46-55	2	6%	0	0%	6%
56-65	0	0%	0	0%	0%
66-75	3	9%	0	0%	9%
Total	16	48%	17	52%	100%
Median age	37.6			28.3	32.8

The first question, following the demographics, primed participants to consider if their consumption patterns had changed since moving to Rosendal. When the participants started the food consumption section, they were informed both verbally and in the written instruction on how to indicate their food intake and what is considered local (from Sweden, as explained above). Participants were reminded about the concept of local since Joosse (2014) shows there is a general tendency for people to assume what local and regional mean.

A	**2**
B	**6**
C	**6**
D	**5**
E	**6**
F	**7**

Figure 6. Map of Rosendal and the number of participants per region (edited from Uppsala Kommun, 2015c).

For the 24-hour recall, participants were instructed to indicate their foods separately, or to list the quantity (g) for the ingredients of different foodstuffs individually and to indicate any beverages (ml) apart from water. In addition, they were encouraged to use the food atlas to help with portion size estimations and prompted on potential missed food items. For example, participants were asked if they had any particular food item(s) that might be missing, based on culturally significant food, if they had anything at fika or any fruit or beverage apart from water. After the 24-hour recall, participants were asked what percent of consumed food was local and organic, and if their food consumption differed from the typical day.

When participants reached the weekly estimations table, they were again instructed verbally and in writing on how to conduct the dietary assessment, as an estimate of the amount consumed for each food category in a typical week. Again, participants were asked to indicate the percent local and organic for each food category. Participants, on average, had the most difficulty with this section and found it more difficult to indicate the amount of weekly food consumption, and percent organic and local. To alleviate participant frustration, the food atlas was encouraged. Following the weekly estimations, participants were asked to indicate the hours spent cooking in a week, the amount of food waste per week, the amount of restaurant visits per month, and the amount of money spent of food per month. At the end of the questionnaire, respondents were able to leave any comments.

Overall, the majority of participants completed the questionnaire with moderate to low participant frustration. However, some participants had significant difficulty in recalling what and the quantities of what they ate for either or both of the dietary assessments. For example, some found it very difficult to estimate the amount in aggregated food categories for the weekly estimations whereas others had difficultly remembering exactly what they ate yesterday. Overall, the majority of participants found the food atlas helpful to very helpful. In addition, feedback from two participants said it was a good questionnaire and enjoyed participating.

Still some of the difficulties could impact the results in this study, which is further elaborated on in the discussion (section (De-)Limitations of this thesis). Many nonresponses were a result of busy participants. In some nonresponses, email addresses were given to the interviewer. Subsequently, emails were sent in attempt to set up another time for an in person questionnaire or to complete the questionnaire at their convenience. In all sent emails to potential participants, the questionnaire and the food atlas were included. Out of 22 emails and questionnaires distributed online, four people returned a completed questionnaire. As for difficulty with the in person interview questionnaires, some respondents were moderately to slightly distracted either by children, pets or other conditions. However, in most instances, the distraction did not impact the consistency of their responses and the interviewer was able to help the respondents to stay on track. Despite the difficulties with the questionnaires, it is believed the results are reliable.

Emergy synthesis

While the environmental impact of various foods can be considered under different analytical lenses, what is important is not only to account for what we eat but also the processes of how these foods are produced (Garnett, 2014b). Accordingly, emergy synthesis was chosen to evaluate the renewability and sustainability of the residents' food consumption in Rosendal. This is because emergy synthesis takes into account and measures both the natural and human processes and work that goes into products and services. Whereas, an ecological footprint does not consider the human processes that go into a product or service. In practice, emergy synthesis includes geophysics to value the amount of energy connected to the production and use of natural and human resources (Siche et al., 2008). This also allows emergy to represent environmental and economic values in a common measure, solar emergy (Odum, 1996). With its inclusive scope, holistic measures and systems approach, emergy synthesis is pertinent to understanding the environmental support of food consumption in Rosendal.

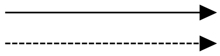
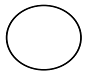
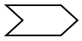
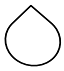
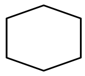
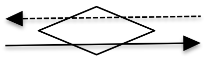
As a quantitative unit and evaluation tool, emergy is used in environmental accounting to determine all flows of available energy supporting a system (Wright & Østergård, 2016) using a thermodynamic base of all forms of energy, resources and human services converted into the units of solar emergy (seJ) (Rydberg, 2012). That is the amount of energy required to make something including energy degraded in the transformation processes according to laws of thermodynamics. Thus, emergy is a donor-based measure of direct and indirect resources or inputs (environmental work and global processes), both past and present, that create or maintain a product or service (Odum, 1996).

Emergy is a universal measure of the work of nature and society on a common basis, seJ (Brown & Ulgiati, 2004a). Often referred to as "energy memory", emergy is all the available energy (exergy) used both directly and indirectly in transforming one energy source to another (Odum, 1996). This includes the 'free' environmental inputs (e.g. rain, sun, wind) and indirect environmental inputs embodied in, for example, fossil fuels, agricultural inputs as well as human labor and services which are often associated with monetary transactions (ibid.). Accordingly, labor is referred to as the direct human labor applied to a system and services account for the indirect labor applied to a process or system from the economy or larger system (Ulgiati & Brown, 2004).

Before an emergy synthesis could be conducted, the empirical data from the food consumption questionnaires was compiled. Therefore, the materials used in the emergy synthesis include questionnaires, Excel for compiling the empirical data and the emergy calculations, Canvas for the drawing the emergy systems diagrams, and the development of tables and figures used in the results section. The food categories were aggregated into nine categories for better comparison to the municipal average by Russo et al. (2014).

Prior to conducting an emergy synthesis, it is important to develop a systems diagram to define the system boundaries, or window of attention, and define the inputs for the system under consideration. The systems diagram language is laid out in Table 3. It is important to define the system boundaries since they affect what is included and excluded in the system. For example, different inputs would be considered if it was a national, municipal or district level system. The purpose of a systems diagram is to conduct a critical inventory of the flows, storages and processes important to the system in question. Going left to right within the diagram, components and flows on the left reflect more available energy flow and decrease going to the right with each successive energy transformation (Ascione et al., 2009). Moreover, items to the right indicate increasing UEVs and position in

Table 3. *Emergy systems diagram language and symbols (Edited from Odum, 1996; Ascione et al., 2009).*

	*Generic resource flow* (money flow when dotted)
	*Source*: outside source, flow-limited energy or resource input
	*Interaction*: interaction among flows with different quality
	*Storage*: storage of resources or assets
	*Consumer*: transforms energy quality
	*Transaction*: economic, resources vs. money
	*Window of attention*: system boundaries

the global energy hierarchy. Hence, it is necessary to evaluate the systems diagram prior to conducting the emergy synthesis.

Once the systems diagram was complete and the inputs were defined, emergy calculations could be applied to the empirical data on food consumption. Appropriate UEVs were found and updated to the new global baseline proposed by Brown and Ulgiati (2016) then applied to the empirical data to convert the amount to their solar emergy (seJ). Renewability of water and electricity were accounted for using FAO (2011a) and Hussein (2015). After determining the total emergy, hypothetical scenarios were developed based of participants' estimated percent of consumption that was local as well as vegetarian diet scenarios. Subsequently, indices and ratios were developed to facilitate comparison, generate perspectives, and help identify especially crucial point to improve. Indices and ratios are also beneficial to emergy synthesis since some consider the balance between the economic inputs to environmental inputs and highlight the importance of renewable resource use (Brown & Ulgiati, 1997; Giannetti et al., 2010).

Semi-structured interview

A semi-structured interview was conducted with the main architect and a landscape architect working for Rosendal Fastigheter during the development of a building in Rosendal, as an example of the sustainability strategies. A semi-structured interview was chosen due to its flexible structure (Louise Barriball & While, 1994). The interview was done to determine if there were any explicit strategies to address food consumption or the sustainability of food consumption. The materials used in the semi-structured interview include an interview guide and an iPod to record the interview. Brief notes were taken during the interview to help understand the context of the dialogue between the main architect, landscape architect and interviewer. Similar to the questionnaire, the interview questions were guided by Foddy (1994) so questions were formulated in chronological order to avoid wrongly priming the interviewees.

The interview started out casually, and the interviewees were given an introduction to the purpose of the study and an estimated duration of the interview. Subsequently, the interviewees were asked if the interview could be recorded. Once agreed, the interviewees were asked about their definition on sustainability following onto other questions related to food consumption and their approach to sustainable design in Rosendal (i.e. if there were any strategies for food consumption). If clarification was needed or more detail was desired, the interviewees were asked follow up questions to improve their responses. Overall, the interview lasted for approximately 50 minutes. The interviewees were thanked for their time, participation and contribution to this study.

5 Results and analysis

In this section, the results and analysis from the questionnaires, emergy synthesis, and interview with the architects from Rosendals Fastigheter are presented.

Food consumption

Once the questionnaires are collected, Excel is used to compile the data. For the 24-hour recall, the participants' recorded food items are categorized into the 14 categories used in the weekly estimations. Where portion size is unclear either due to researcher error or mixed foods, the Swedish food database Livsmedelsverket (2016) is used to estimate portion size of the ingredient(s) based on the participants' estimations. When the food database did not have the food commodity or ingredient portions, food recipes are used to estimate the quantities. For one participant, food intake for the 24-hour recall is extrapolated from weekly estimations since s/he did not record any amounts. Three participants' weekly estimates are extrapolated from their 24-hour recall. An additional participant's fruit consumption is also extrapolated since s/he did not indicate fruit intake, but had eaten fruit in the 24-hour recall. Subsequently, the means for the 24-hour recall and weekly estimates as well as the following questions are calculated. The mean food consumption is categorized into nine food categories following the above-mentioned sources and for better comparison to the municipal average. The categories of fruits and vegetables, starchy vegetables and pulses are combined as well as dairy and eggs. Sweets is included into the cereals and derived category since it is assumed that Russo et al. (2014) include sugar in this category. Additionally, it is assumed all stimulants are coffee. Finally, the mean of the 24-hour and weekly estimate averages is calculated to calibrate for potential over and under estimations in each food intake assessment.

The results from the food consumption questionnaies are the basis for the data on the estimated monthly and yearly food consumption (emergy synthesis) of the inhabitants in Rosendal. When asked if their food consumptions patterns changed since moving to Rosendal, 23 participants indicated that there food consumption patterns had changed whereas 10 indicated no change. The reasons for food consumption change are a change in stores due to the move, more consumption of ready-made foods, and variations in the amount and type of food intake (see Table 4). It is unknown why some indicate more ready-made foods since it was not specified, but all participants who did are younger than 25. Variations in the amount and type of food range from change in business and health reasons. In addition, three participants indicate the use of food bag delivery services, two of which specify increasing frequency of food bag delivery since moving to Rosendal. One participant's increase in food bag service is correlated to reduced trips to the store due to a longer distance. The other wanted to try food bag services.

When asked whether their food consumption was different than the typical day, following the 24-hour recall, a significant number of participants, 19 out of 33 indicate that their food consumption was different. Table 5 outlines the different response for why the participants' food diverged from the typical day. Some indicate that their food consumption was different because they had a day off work, ate a different amount than usual, and other work related reasons (e.g. eating at a restaurant over lunch).

The results of the 24-hour recall differed from those of the respondents' weekly estimations, shown in Table 6. On average, food consumption from the 24-hour recall is lower, which suggests that the respondents could have underestimated their food intake. In particular, alcohol consumption is much lower in the 24-hour recall than the weekly estimates. On the other hand, the week-

Table 4. *Changes in food consumption since move to Rosendal.*

Changes in food consumption	**Number of respondents**
Change of business	8[a, d]
More consumption of premade (box), junk or fast food	3[a]
Buys own food, eat on own terms (independence)	2
Goes to the store less (larger stores further away)	2[b]
Start or increased use of food bag delivery	2[b]
Less food consumption	2[c]
Everything changed, new town (use to buy from farmer)	1
Healthier food consumption	1
More vegetarian food	1[e]
More eco-friendly, ecological food	1[c]
Goes to the store more (easier)	1
Cooks more	1[d]
Cooks less	1
Buys cheaper food	1[e]
Fewer restaurant visits	1
No changes	10

Note: the letters a, b, c, d, and e represent where a participant indicates another change since moving to Rosendal.

Table 5. *Reasons why food consumption was reported different than the typical day in the 24-hour recall.*

Response	**Number of respondents**
Day off	6[a, b, c]
Not homemade, less climate friendly	1
Ate less organic	1
Ate less than usual	4[b]
Ate at a restaurant	3[a]
Food bag varies	1
Ate more of a food group	2
Fluxuates due to economical reasons	1
Missed a meal	2[c]
Difficulty with food consumption	1

Note the letters a, b and c indicate where the respondent a, b, and c, include another reason for atypical food consumption.

Table 6. *Food consumption results in Rosendal.*

Food Categories	24-hour Recall	Weekly Estimation	Mean	Percent Local
Cereals and derived	9.03	7.71	8.37	25.7%
Fruits and vegetables	11.08	14.97	13.03	39.6%
Dairy and eggs	5.15	10.71	7.93	56.1%
Meat	3.15	3.71	3.43	42.5%
Fish	0.78	1.76	1.27	28.0%
Oils	0.96	1.21	1.08	29.5%
Stimulants	6.63	9.67	8.15	19.1%
Non-alcoholic beverages	7.80	10.24	9.02	14.1%
Alcoholic beverages	0.69	7.20	3.94	11.8%

ly estimations could be overestimated as they are typically higher than the 24-hour recall. To accommodate for possible over- and under- estimation, the mean of the 24-hour recall and weekly estimations is used for food consumption. The mean percent of estimated local food for each category is also used.

Following the weekly estimations, participants were asked to document the time they spent cooking per week, amount of food waste per week and the monthly amount spent on groceries (see Table 7). On average, residents in Rosendal cook approximately 7 hours and discard 2.7 kilograms of food per week. The average resident in Rosendal estimates that approximately 2500 SEK is spent on food per month.

Table 7. *Mean time spent cooking, food waste and money spent on food.*

Item	Amount	Unit
Cook	6.79	hr/week
Food waste	2.65	kg/week
Money spent on food	2518	SEK/month

Food consumption for the typical Rosendal resident is presented in monthly averages per capita, detailed in Table 8. The results show that in a month, the average person in Rosendal consumes 56.22 kilograms of food, approximately 12 to 56 percent of which is estimated to be from Sweden (or local; see in Table 6). Based on the price per unit used in Russo et al. (2014), the monthly amount spent on food is 1470 SEK (~ 162 USD) on food whereas the participants estimate that they spend 2518 SEK (~ 277 USD)[4] on food per month (Table 7). The majority of

Table 8. *Food consumption in Rosendal (month/capita).*

Input flows	Units	Amount*	Price (SEK/unit)	Cost (SEK/Month)	Nutritional value** (Kcal/day)	% kg	% cost	% Kcal
Fish	kg	1.27	160	90	76	2%	6%	3%
Meat	kg	3.43	95	279	164	6%	19%	6%
Fruit and vegetables	kg	13.03	37	278	439	23%	19%	17%
Dairy and eggs	kg	7.93	44	231	472	14%	16%	19%
Cereals and derived	kg	8.37	20	229	516	15%	15%	20%
Fats	kg	1.09	96	40	320	2%	3%	13%
Beverages, alcoholic	kg	3.94	105	159	133	7%	11%	5%
Beverages, stimulants	kg	8.15	4.7	38	0	14%	3%	0%
Beverages, non-alcoholic	kg	9.02	15	135	407	16%	9%	16%
Total	kg	56.22	576.66	1479	2528	100%	100%	100%

* Mean of the 24-hour recall and weekly estimations. ** Estimates from Livsmedelsdatabasen (Livsmedelsverket 2016).

food expenses are from meat and fruits and vegetables. Combined they expend 48% of the money spent on food. Figure 7 shows the most consumed food (kg) is fruits and vegetables followed by non-alcoholic beverage consumption. These two food categories also contribute the percent of kilocalories (Figure 8). However, not all foods are created equal. Cereals and derived products contribute more in terms of kilocalories and less in kilograms than the highest consumed products in terms of kilograms.

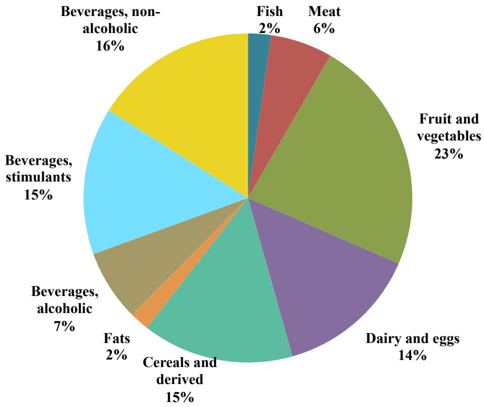


Figure 7. Percent of total kilograms for each food category consumed in Rosendal.

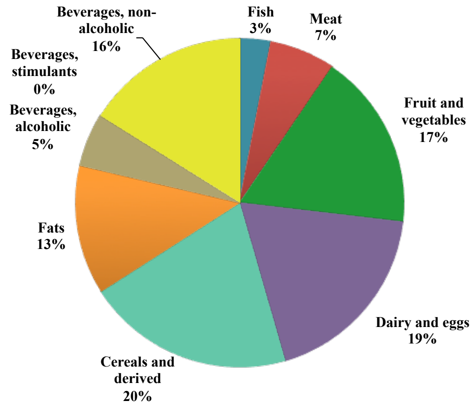


Figure 8. Percent of total kilocalories for each food category consumed in Rosendal.

In comparison to the municipal average, Rosendal's food consumption is higher in terms of caloric intake (Table 9). The caloric intake of Rosendal is closer to the NHS (2016) recommendation of 2,000 to 2,500 calories per day for a female and male, respectively. This suggests that the results of this study could be relatively more representative of the actual food intake in Rosendal compared to the municipal average assessed by Russo et al. (2014). However, both may be slight underestimations. As seen in Figure 9, Rosendal's consumption is higher for nearly every food category except for cereals. The decrease seen in cereals correlates the current food trend of decreasing cereal consumption with an increase in meat and dairy intake (Tilman & Clark, 2014). Since Russo et al. (2014) also include rural

Table 9**.** *Comparison of food consumption in Rosendal to the municipal average.*

Input flows	**Units**	**Amount** (this study)	**Nutritional value*** (Kcal/day)	**Amount** (Russo et al., 2014)	**Nutritional value*** (Kcal/day)
Fish	kg	1.27	76	0.56	34
Meat	kg	3.43	164	2.94	140
Fruit and vegetables	kg	13.03	439	7.50	253
Dairy and eggs	kg	7.93	472	5.31	316
Cereals and derived	kg	8.37	516	11.42	704
Fats	kg	1.09	320	0.42	123
Beverages, alcoholic	kg	3.94	133	1.51	51
Beverages, stimulants	kg	8.15	0	8.15**	0
Beverages, non-alcoholic	kg	9.02	407	9.02**	407
Total	kg	56.22	2528	29.66	2028

* Estimates from Livsmedelsdatabasen, Livsmedelsverket 2016. ** Data from this study.

areas, the results for Rosendal are in line with current research and trends in food consumption between rural and urban areas. Various studies show urban environments consume more meat and dairy products (and oils/fats) than their rural counterparts (Guo et al., 2000; Ma et al., 2006; Kearney, 2010; Tilman & Clark, 2014).

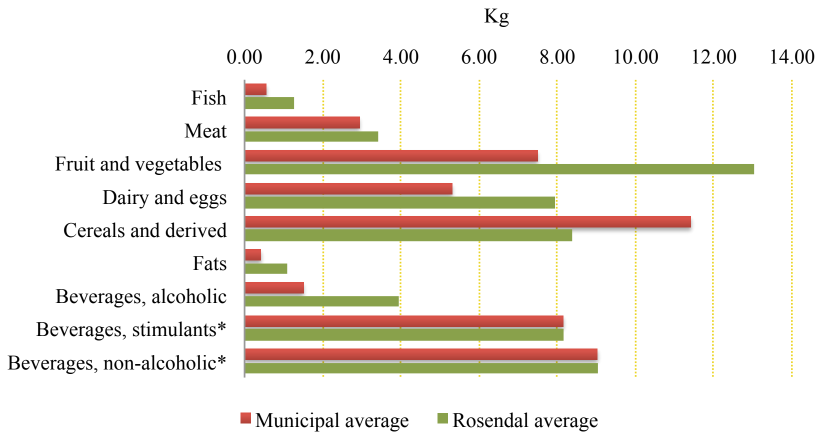


Figure 9. Food consumption in Rosendal and the municipality of Uppsala (kg/month).
* Data from this study.

Emergy synthesis

The yearly per capita resource basis for food consumption in Rosendal, extrapolated from the questionnaire results, is evaluated using emergy as a measure of the indirect and direct resources that support food consumption and the environmental load of inhabitants in Rosendal. Before conducting the emergy synthesis, food preparation and consumption in the Rosendal district are depicted in a system's diagram, drawn according to a standardized energy systems language (Odum, 1996, p. 5), seen in Table 3 in the Methods section. The system's diagram defines the boundary, or window of attention, for the system involved in food consumption in Rosendal, its main driving forces, generated outputs and the main interactions among system components and the larger system of Uppsala. Figure 10 outlines the food systems diagram by combining all resources and components to show the inputs, outputs and interactions that support food consumption in Rosendal. In addition, Figure 12 (see page 35) is used to illustrate the definitions of the input categories used to calculate the emergy indices and ratios.

The larger frame seen in Figure 10 includes Uppsala municipality and the inner frame represents everyday, typical food preparation and consumption for the residents in Rosendal. According to systems theory and emergy diagramming conventions, this represents the main system boundary of this study, expressed as a subsystem embedded in the next larger scale of Uppsala city, and in extension the global food system. Resource inputs (R, N, F) from outside of the studied system

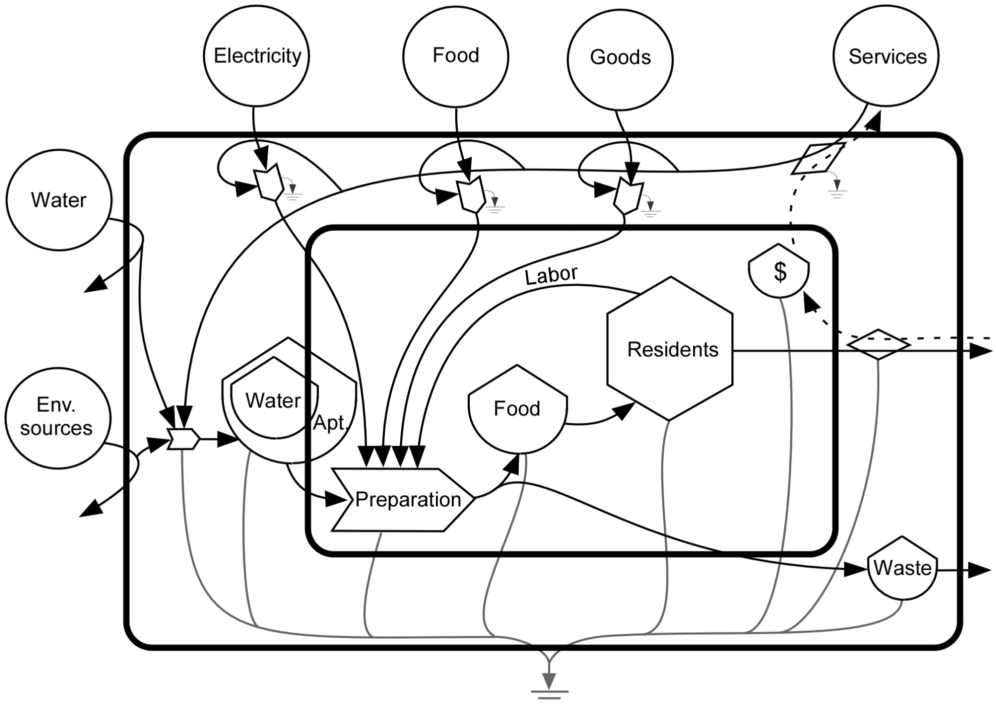


Figure 10. Food systems diagram for Rosendal. Variables are defined in Table 10.

are reported as E20 seJ/yr, and inside the frame as percentage of resources used in the food system (529.1E20 seJ).

Local renewable (R) and non-renewable (N) inputs in addition to imported, or purchased, inputs (F) support food consumption in a variety of ways, seen on the left and top of the diagram. From these the outputs are generated, represented as outflows on the right side of the diagram. Going left to right the transformity and emergy increase. Accordingly, money flows are also represented on the right side of the diagram and flow out as payments for the human service required for producing and delivering food to consumers in Rosendal. Local renewable inputs (R) for food consumption in Rosendal are defined as solar insolation, the fraction renewable of fresh water and electricity used inside the apartments for cooking. Based off of the global average by FAO (2011a), 60% of the water is considered renewable and the remainder is defined as N. Whereas, 55.91% of electricity is considered R based on Hussein (2016) and the remainder is defined as F. To avoid double counting according to emergy algebra calculation, solar insolation has been removed from the calculations since it drives the other processes generating R (water) (Odum, 1996). Here, R refers to those resources that are regenerative within the system boundaries whereas those of F are imported from a larger system.

Local non-renewable inputs (N) are defined as the non-renewable percent of water and the physical structures, or apartments, and their degradation over an assumed 50-year span. In the calculations for N, it is assumed that apartments are all the same size, based of the mean flat size indicated by the participants. Imported inputs (F) are defined as the electricity and appliances used for cooking, foods consumed and human services used in the processes of the global and Swedish food system. Services include all the indirect environmental and economic support to food at all levels, including historical emergy. This also includes the resources used in distribution, processing, and packaging as well as human resources and knowledge. Accordingly, imported inputs and feedback from the economy are considered as the same type of flow, seen in Figure 12 (p. 35). From the inputs, the outputs are produced. The output comprises of waste and urban life, or labor, expressed as two inherently different types of co-products though sharing the same emergy inputs. A portion of labor is considered a feedback within this system for the hours spent cooking. Here urban life is used to contextualize that residents live in an urban district and the food they provides them energy to live out their urban daily lives, whether it be used for work or pleasure.

As mentioned above, emergy takes into account the labor and services, or human activity, that go into a final product. Labor and services are the additional work applied through human activity to the raw resources generated by the biosphere, which adds to it energy quality and economic cost (Russo et al., 2014). Both are main factors for most production processes and should not be disregarded when examining human managed activities and socio-ecological systems (ibid.). According to emergy theory, what makes product valuable is both the environmental and human work that go into refined resources. Labor refers the direct human labor applied to a system and services refer to the indirect labor applied to a process or system from the economy or larger scale (Ulgiati & Brown, 2014; Russo et al., 2014). Both have a cost that can to be accounted for.

Once the diagram and system boundaries were describe, the empirical data was used to set up in an emergy evaluation table (Table 10). Emergy per capita is used since it is unknown how many residents live in Rosendal, and the goal is to understand the average emergy of people living there. The results show that as much as 93.6% of all inputs into food consumption in Rosendal are imported resources (F). Most of these resources are considered non-renewable since they originate outside the systems boundaries. Resources that are considered local, but non-renewable (N) contribute nearly 5.5% of the system's emergy flows, in this case the resources needed for the physical structure (kitchen) and its lifespan as well as the percent of water that is non-renewable. This leaves less than 1% of the resources used in food consumption as local and renewable (i.e. fraction renewable water and electricity). An implication of these results is that food consumption in Rosendal is highly dependent on imported and (locally) non-renewable resources.

Table 10. *Emergy flows supporting food preparation and consumption in Rosendal (per capita/year). See Appendix 3 for calculations and footnotes.*

Item	Unit	Date (units/yr)	Unit Emergy Value (UEV) (seJ/unit)	References	Solar Emergy	Percent
Local renewable inputs (R)						
1 Sun	J	1.63E+10	1	a, b, c, d	1.63E+10	0.00%
2 Water	J	7.29E+07	5.67E+05	e, f, g, q, s	4.13E+13	0.99%
Local non-renewable inputs (N)						
3 Physical structure, apartment	hrs	3.53E+02	6.51E+11	p, g	2.30E+14	5.50%
Imported inputs (F)						
4 Electricity	J	1.25E+09	1.72E+05	f, g, h, m, r, t	2.15E+14	5.14%
5 Non-alcoholic beverages	J	1.49E+08	2.29E+05	f, g, l, r	3.43E+13	0.82%
6 Stimulants	g	4.89E+06	7.28E+05	f, g, i, j, k	3.56E+12	0.09%
7 Cereals and derived	g	1.00E+05	4.17E+08	f, g	4.19E+13	1.00%
8 Fruits and vegetables	g	1.56E+05	4.91E+08	f, g	7.68E+13	1.84%
9 Dairy and eggs	g	9.52E+04	1.06E+09	f, g	1.01E+14	2.42%
10 Alcoholic beverages	g	4.73E+01	1.10E+09	f, g	5.18E+10	0.001%
11 Appliances	g	3.39E+02	6.70E+09	g, m, n	1.77E+12	0.04%
12 Fats	g	1.30E+04	1.95E+10	f, g	2.54E+14	6.09%
13 Fish	g	1.52E+04	3.38E+10	f, g	5.15E+14	12.32%
14 Meat	g	4.12E+04	3.73E+10	f, g	1.53E+15	36.74%
15 Services	SEK	3.36E+03	3.35E+11	f, g, m, o	1.13E+15	27.01%
Total emergy input (Y)	seJ				4.18E+15	100.00%
Outputs *Unit emergy values (UEVs), calculated*						
15 Waste	g	1.38E+05	3.03E+10	seJ/g	incl. services	
16 Labor (urban life)	hr	8.41E+03	4.97E+11	seJ/hr		
	g	1.38E+05	2.21E+10	seJ/g	excl. services	
	hr	8.41E+03	3.63E+11	seJ/hr		

Imported inputs have the largest contribution to the system. Figure 11 shows the percent of each resource input. Meat requires the most imported resources, nearly 40% (38.9%) of the total purchased resources. Services follow at nearly 30% (28.8%) followed by fish at 13% after which comes electricity and fats (6.7 and

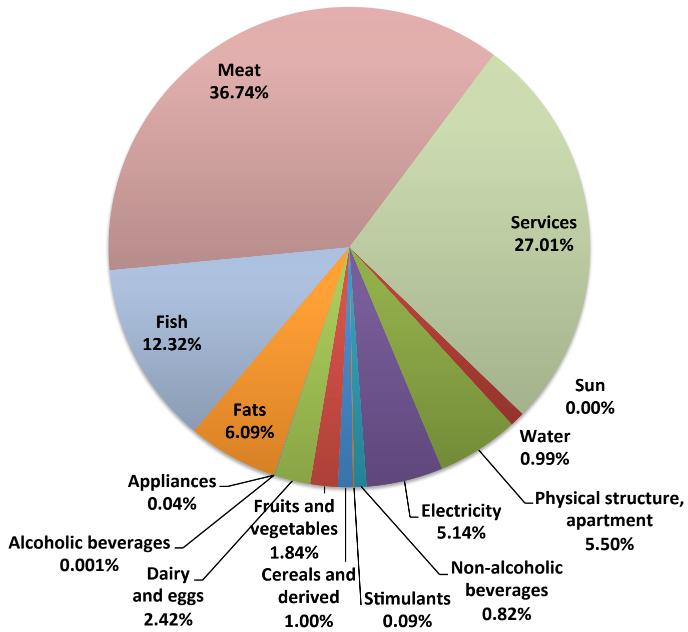


Figure 11. Solar emergy of the resource inputs that support food consumption of residents in Rosendal.

6.4, respectively). The lowest share of imported emergy inputs derives from alcoholic beverages, 0.002% of total imported inputs. The four lowest imported inputs combined, all beverages (excluding dairy products) and appliances, have lower imported inputs (1.02%) than the fifth lowest input of cereals and derived products (1.06%). Whereas, all inputs excluding fish, meat and services account for 19.8% of all imported inputs; and, all inputs excluding meat and services account for 32.8% of all imported inputs, less than meat alone.

The relationship of emergy to kilogram, cost and Kilocalorie of food varies between each food items. Meat has a high impact yet a moderate nutrient contribution in terms of kilocalories and is one of the most expensive food items. On the other hand, cereals have low emergy in relation to meat and fish yet have one of the highest kilocalorie contributions for the price. Dairy and eggs also notably contribute to kilocalories and kilogram but at higher emergy and monetary cost.

When accounting for services and labor, it is important to avoid double counting. If a solar transformity already includes the services and labor, the physical amount of a given input flow should not be multiplied by its economic cost. In this study, only the services of monetary flows were accounted for in the inputs. It is assumed Russo et al. (2014) use services in their UEVs, which explains why this study does not account for them in calculations for services. Therefore, the new UEVs were calculated on the basis of additional sources, other than Russo et al. (2014), to avoid double counting. The new UEVs are calculated for the co-products waste and urban life (labor), based on food preparation and consumption alone, with and without including services. Furthermore, labor is considered as an internal feedback within the system and an output of the system. The labor that is fed back is subtracted from total labor to get the amount of labor output.

Comparing food consumption in Rosendal with the municipal average (Russo et al., 2014) similarities and differences emerge, detailed in Table 11. When excluding services, both studies show that meat has the highest solar emergy at 60% and 48%, respectively. However, large differences are visible between the contribution

Table 11. *Comparison of the emergy supporting food consumption in Rosendal and Uppsala.*

Item	Units	Rosendal	Uppsala	Percent Rosendal	Percent Municipality
Non-alcoholic beverages	seJ/yr	3.43E+13	3.43E+13*	1.34%	12.55%
Stimulants	seJ/yr	3.56E+12	3.56E+12*	0.14%	1.31%
Cereals and derived	seJ/yr	4.19E+13	6.75E+12	1.63%	2.48%
Fruits and vegetables	seJ/yr	7.68E+13	3.76E+13	3.00%	13.77%
Dairy and eggs	seJ/yr	1.01E+14	6.79E+12	3.95%	2.49%
Alcoholic beverages	seJ/yr	5.18E+10	1.99E+13	0.002%	7.31%
Fats	seJ/yr	2.54E+14	9.79E+12	9.92%	3.59%
Fish	seJ/yr	5.15E+14	2.27E+13	20.09%	8.33%
Meat	seJ/yr	1.53E+15	1.31E+14	59.92%	48.18%
Total	seJ/yr	2.56E+15	2.73E+14	100.00%	100.00%

*Data from this study.

of fruits and vegetables and fish. In this study, fish contributes 20% of all food's solar emergy, more than double the municipal average. Whereas, fruits and vegetables are the second largest consumer of solar emergy for the municipal average, in Rosendal this only accounts for 3% of the solar emergy. Another distinction between the results of this study and the municipal average is alcohol consumption. The municipal average for alcoholic beverages is much larger than the results from this study.

Hypothetical scenarios

In order to evaluate potential implications of alternative food systems for Rosendal in comparison to the results of this study, three hypothetical scenarios are developed and compared to the results of this study. The scenarios are defined in the following section. In addition, Figure 12 provides a visualization and definition of the input categories used in the emergy indices and hypothetical scenarios.

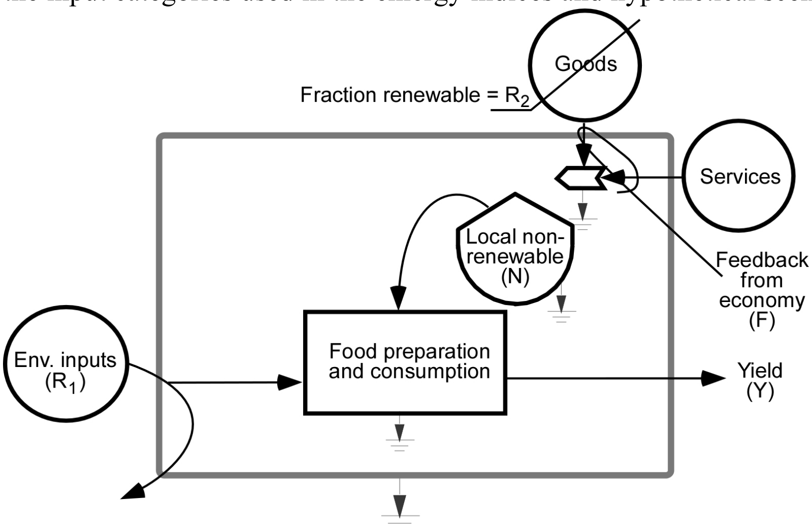


Figure 12. Aggregated systems diagram describing definitions of the input categories used to calculate emergy indices.

<u>Scenario A1</u>

This study according to emergy conventions, $R=R_1$, N=N, F=F.

<u>Scenario A2</u>

The window of attention for the current study is expanded to include the fraction of food that is estimated in the questionnaire responses to be locally produced, i.e. Sweden (see Table 6). Therefore, the percentage of each food category that is estimated as local in Table 6 is assumed 100% renewable, accounted for as local environmental inputs (R) and deducted from imported inputs (F). This scenario can be understood as locally renewable food items in combination with food imports, $R=R_1+R_2$, N=N, $F=F-R_2$.

Scenario B1

Using the basis of this study, Scenario B1 is a hypothetical example assuming a 100% vegetarian diet with all other details remaining the same, i.e. supplied through imports. To converge to a vegetarian diet, the units (kg) of meat and fish were accounted for as fruits and vegetables. The scenario can be understood as a vegetarian diet that is business as usual and according to emergy conventions, $R=R_{1,}$ $N=N_{,}$ $F=F$.

Scenario B2

As a hypothetical example, scenario B2 combines scenarios A2 (local renewable food) and B1 (vegetarian diet). This scenario can be understood as a local vegetarian diet, $R=R_{1+}R_{2,}$ $N=N$, $F=F-R2$.

The results of the resource use and output in all four scenarios are detailed in Table 12. The results shows show that both A scenarios and B scenarios have the

Table 12**.** *Resource use summary for four food consumption scenarios in Rosendal.*

Components	Units	Scenario A1	Scenario A2	Scenario B1	Scenario B2
R *local renewable*	seJ/capita/yr	1.45E+14	1.11E+15	1.74E+14	3.57E+14
N *local non-renewable*	seJ/capita/yr	2.46E+14	2.46E+14	2.46E+14	2.46E+14
F *imported inputs*	seJ/capita/yr	3.79E+15	2.82E+15	1.78E+15	1.59E+15
Y *total emergy input*	seJ/capita/yr	4.18E+15	4.18E+15	2.19E+15	2.19E+15

same total emergy input, 4.18E+15 and 2.19E+15 respectively. Figure 13 shows the variations of F and R in the four scenarios. Scenario A2 has the most local, renewable resources followed by scenario B2. Both ‘business as usual’ scenarios, A1 and B1, have higher imported inputs (F) than those that expand the window of reference to include the estimated fraction of local food consumption.

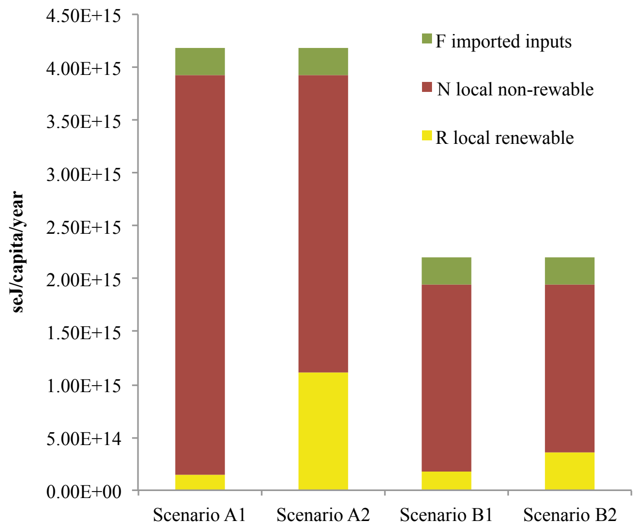


Figure 13. Emergy profile for the four food consumption scenarios.

Emergy indices and ratios

In order to facilitate the comparison and generate perspectives, emergy indices and ratios are used. Indices and ratios also help identify crucial points for improvement, and thereby explore alternative development paths that could deliver the same function yet in a more efficient and sustainable manner. The following ratios are used to facilitate comparison and deeper understanding of the emergy support to food consumption in Rosendal: emergy investment ratio, emergy yield ratio, percent renewable, environmental loading ratio, emergy sustainability index and solar share. Together, these indices and ratios are used to evaluate over all resource support to the specific diets and scenarios in Rosendal.

The emergy yield ratio (EYR) measures the potential contribution of a system to the main economy because of exploited local resources. EYR is the ratio of the total emergy input, or Y, driving a process divided by the imported emergy inputs (F). As an indicator of the yield compared to inputs other than local, EYR gives a measure of the ability of a system to exploit local resources and the net emergy to society (Brown & Ulgiati, 1997; Brown & Ulgiati, 2004a).

The emergy investment ratio (EIR) is not an independent index and is linked to the EYR. It evaluates whether a system is a good user of the emergy that is invested in comparison with alternatives. EIR is the ratio of F emergy that is fed back from outside the system to the indigenous emergy inputs, both renewable and non-renewable (R + N) (ibid.).

The percent renewable is a ratio that is sometimes calculated in emergy synthesis depending on the type and scale of the system. Percent renewable emergy is the percent of the total emergy driving a system that is from renewable sources (R) or the ratio of renewable emergy to total emergy used. Only systems with high percent renewability are considered sustainable (ibid.).

Environmental loading ratio (ELR) complements the information provided by the UEVs and makes a clear distinction between non-renewable and renewable resources (Brown & Ulgiati, 1997). As an indicator of the pressure the system places on the local ecosystem, it assesses the emergy that is loaded into the system (Rosendal). It is the ratio of the non-renewable (N) and imported (F) emergy to the local, renewable emergy (R). ELR can be considered a measure of potential ecosystem stress that is a result of a transformation process (Brown & Ulgiati, 1997; Brown & Ulgiati, 2004a).

The emergy sustainability index (ESI) is connected to EYR and ELR. It is a measure of the potential contribution of a process, system or resource to the economy per unit of environmental loading. The ESI is the ratio of the EYR to ELR (ibid.).

Solar cost index (SCI) is an index derived from the total incoming solar emergy coming. It measures the magnitude of the solar share that is used of the emergy (energy and resources) used in product or service (Brown, 2010). The idea of a solar share is similar to the concept of a carrying capacity, discussed in the Background section. It is used to evaluate various products and processes to highlight the emergy intensity of human activities (products and services) and share of the world's total available emergy. It is the ratio of the emergy of a good or service, in this case food items, to the solar share of global renewable emergy. Solar share is found by taking the global renewable emergy constant or global emergy baseline (1.21E+25) divided by the global population (7.42E+09) (ibid.). Therefore, if the SCI is two then the emergy content of a product or service is twice the solar share of the average individual in the world.

The percent locally renewable emergy is an important factor for the overall sustainability and renewability of a system. It is so important that only systems with a high percent of renewability are considered sustainable (Brown & Ulgiati, 2004a). Therefore, 3.47 percent renewable emergy in Rosendal indicates the food consumption in this district may not be considered sustainable. This factor also significantly influences the rest of the emergy indices and ratios, seen in Table 13.

Table 13. *Emergy-based indices for food consumption in Rosendal.*

Emergy-based indicators	Expression	Rosendal
Emergy Investment Ratio (EIR)	F/R	9.68
Emergy Yield Ratio (EYR)	Y/F	1.10
% Locally renewable	R/total emergy	3.47%
Environmental Loading Ratio (ELR)	(F+N)/R	27.85
Emergy Sustainability Index (ESI)	EYR/ELR	0.04
Solar Cost Index (SCI)	Y/Solar Share	2.56

If a system does not make use of its local resources (e.g. harness solar insolation for energy or grow and supply its own food), it means that a lot of investments or imported inputs are necessary to drive the system. This explains the high EIR 9.68 because substantial investments are needed to support food consumption in Rosendal, which are required to indefinitely maintain it. This is sometimes referred to as high throughput systems. Additionally, this implies high vulnerability due to reliance on constant inflows of external inputs. Furthermore, a high degree of dependence on other systems indicates weakness in a competitive capacity (long-term sustainability and self-sufficiency) because the control of resource availability and maintenance does not belong to the system (i.e. residents living in Rosendal) (Pulselli et al., 2008).

The EYR of Rosendal is slightly higher than one, the lowest possible value and indicates it is not an efficient (good) system. Values $\simeq 1$ indicate that the system delivers the same amount of emergy that drives it, and is thus incapable of efficiently using available local resources (Brown & Ulgiati, 2004a). Accordingly, food consumption in Rosendal does not provide significant net emergy to the economy and merely transforms resources that are available from previous processes or systems (ibid.). Therefore, it is considered as a consumer system (ibid.).

For ELR, anything above ten is considered high and inefficient (bad) (Brown & Ulgiati, 2004a). Since the ELR in this system is 23.29, this indicates that the food system requires significant environmental support from large flows of concentrated non-renewable and imported emergy. This implies greater distance from the development of natural processes that could potentially be generated locally.

By combining EYR and ELR, the emergy sustainability index (ESI) of 0.04 is created for Rosendal. An ESI < 1, similar to the EYR, indicates it is a highly developed consumer-orientated system. Accordingly, the system does not contribute to society without greatly loading or importing large resources inputs.

The SCI, derived from the solar share, is comparable to the concept of the global carrying capacity by relating it to the flux of renewable emergy. Using SCI can help people grasp the magnitude of our energy and resource use and show whether we are using more or less than our fair share (Brown, 2010). Dividing the total emergy of food consumption by the solar share per individual, the SCI shows that the average person in Rosendal overshoots his/her solar share 2.56 times. This means a person in Rosendal consumes 2.56 times of the global share per person, more than the fair share (ibid.).

The emergy-based indicators for the four scenarios in Rosendal show that Scenario A2 ranks the most sustainable on all aspects except the SCI (see Table 14). However, since the EIR for scenario A1 is twice all the other scenarios, this suggests that a shift to any of the three hypothetical scenarios would improve the sustainability (i.e. the system would be less invested in other, external systems). Based on the EYR, if more food is sourced locally (A2) then efficient use of local resources increases. Though, switching to a vegetarian diet also benefits the EYR. The percent renewable also increases respectively to the amount of local food, with lower increases seen in the vegetarian based diets. Furthermore, A2 shows the highest reduction in the environmental loading or stress from the food consumption of the inhabitants in Rosendal. Likewise, the ESI shows the same trend where Scenario A2 is considered the most sustainable followed by B2, B1, and lastly the current scenario A1.

Table 14. *Emergy-based indices for the four food consumption scenarios in Rosendal.*

Name of Index	Expression	Scenario A1	Scenario A2	Scenario B1	Scenario B2
Emergy Investment Ratio (EIR)	F/(R+N)	9.68	2.07	4.23	2.64
Emergy Yield Ratio (EYR)	Y/F	1.10	1.48	1.24	1.38
Percent Renewable (%Renew)	R/total emergy	3.47%	26.66%	7.91%	16.27%
Environmental Loading Ratio (ELR)	(F+N)/R	27.85	2.75	11.65	5.15
Emergy Sustainability Index (ESI)	EYR/ELR	0.04	0.54	0.11	0.27
Solar Cost Index (SCI)	Y/Solar Share	2.56	2.56	1.35	1.35

Interview with Rosendal Fastigheter

During an interview on December 6, 2016 with the architect and an intern landscape architect, the aim to determine whether there are any explicit food strategies in Rosendal to influence sustainable consumption is addressed. When asked how they defined sustainability, both recognize the importance of a balance between ecological, social and economic sustainability but find it difficult accomplish all three equally. Accordingly, both place a stronger emphasis on social and ecological sustainability in their definitions of sustainability and sustainable districts, which is applied in Rosendal (Architect, 2016; Intern Landscape Architect, 2016). For example, the Architect (2016) states that it is about giving something back to what is removed from nature in addition to promoting socialization and use of the built environment. Accordingly, the term green, as is promoted for the district, is seen to reflect that is more sustainable, green in nature, and use more sustainable materials (i.e. wood) (Architect, 2016). In addition, green can be seen to reflect more greenery (i.e. trees and plants), sustainable materials and energy saving (Intern Landscape Architect, 2016). An aspect of social sustainability that benefits the environment includes fruit and berry bushes and planting beds on the terraces.

However, when asked whether food consumption was consider or if there is a food strategy in Rosendal, both indicate that neither had been considered but (Architect, 2016) thought maybe they should since it is a big part [of life] (Intern Landscape Architect, 2016). While both indicate that the addition of planting beds and fruit bushes in Rosendal could be considered part of the food strategy, there really is no food strategy and was not one at the start of Rosendal (Architect, 2016; Intern Landscape Architect, 2016). They both indicate that the addition of planting beds is for social sustainability as a conversation piece among neighbors and friends (ibid.). In addition, there is a concept for window gardens, which were inspired by academics from the Resilient Center (Architect, 2016). However, the architect mentions that the hope for these is to inspire sustainable lifestyles, including growing fruits and vegetables, but did not explicitly consider this for the sustainability of food consumption (ibid.). Though, food is considered an important aspect, it is more so considered from the aspect of convenience, to have stores and diverse restaurants near, and a social opportunity.

When asked what they saw as the main challenge to create a more sustainable food system in Rosendal, both indicate that external people should be involved to help developers communicate (Architect, 2016; Intern Landscape Architect, 2016). The intern landscape architect (2016) suggested this could help developers plan their buildings to create a mix of different restaurants and amenities. According to the architect (2016), it would be good for someone from the municipality to organize it, but states that often the market decides it.

6 Discussion

The results of this study show that Rosendal is a consumer system, and food consumption in Rosendal is greater in (caloric) quantity and total emergy than the municipal study conducted by Russo et al. (2014). This indicates that the average resident in Rosendal requires more environmental support for the food they consume when compared to the municipal average. When looking at the scenarios, the most renewable and therefore sustainable scenario (A2) is produced when diet remains the same but is derived from local renewable sources. This could be due to how emergy defines renewability, as resources that are renewed locally or internal by the system itself. Arguably, since we expanded the window of reference to consider a portion of imported inputs as R in this hypothetical scenario then renewable imported inputs could also improve the renewability of the system. Moreover, the architects at Rosendal Fastigheter unveiled that there had not been any strategies for food consumption in place when planning for the area. These results will be further discussed in this section.

When participants were asked why they moved to Rosendal, six out of 33 indicate the reason for moving to Rosendal as moving out of their childhood homes, which corresponds to the high percentage of participants between the ages of 18 and 25 (45%). Since the move, the number one change in consumption patterns for all participants (8 of 33) is a change in grocery stores. For one, this change resulted in buying and consuming more ecological (organic) food while another indicated using delivery services more due to the distance from the store. In addition, three participants indicated that they consume more 'junk' food or premade box meals, all were under the age of 25, a high school degree is the highest level of education for two, and one had recently moved from his/her childhood home.

In the demographic under 30, five participants follow a vegetarian or plant-based diet for ethical, environmental and health reasons. Likewise, an additional participant eats more vegetarian meals since moving to Rosendal. Out of these six participants, all but one have or are in the processes of obtaining a university degree. On the other hand, two respondents in the older demographics, with at least a high school diploma, indicate that they are aware they consume too much meat or coffee, but have not reduced their consumption. This could suggest that education and age are factors that potentially influence (changes in) food consumption more than, for example, policy or physical measures in the built environment. Furthermore, Rosendal may be an important area for young people starting their lives, and this type of resident has yet to determine their dietary and consumption practices.

When conducting and compiling the data from the 24-hour recall, it became apparent that a significant number of participants identified their food consumption as different than the typical day. Out of 33 participants, 19 stress that yesterday's food consumption was atypical. The top reason for abnormal food consumption is due to a day off or a weekend day. Other reasons include eating less food in general or more of a particular food group, eating at a restaurant, or missing a meal. The high number of respondents that note their food consumption as different could be a result of what Cade et al. (2002) describe as the inclination of some respondents to report what they consider as desirable responses in a dietary or food intake assessments. Thus, it is conceivable that many of the respondents felt that their responses were not desirable according to the reasons they consumed differently from a typical day. However, as mentioned in methods section, since the mean group values are what is important the variations should average out among the participants.

Food consumption

The results show that the average resident in Rosendal consumes approximately 56 kilograms of food in a given month. Based off the participants' estimations, 10.6 kg or 19% of food is wasted per month. When comparing the participants estimated amount spent on food per month (Table 7) and the amount seen in Table 8 (based on the price of food indicated by Russo et al., 2014), the participants' estimations are higher and closer to the national average. Though the prices could be marginally outdated in Russo's study, it could imply that food consumption is still underestimated. However, when compared to food consumption in the municipality, it is likely more representative of the sample since it is closer to the recommended daily caloric intake of 2,500 for a healthy, balanced male diet and 2,000 calories for a balanced, healthy female diet (NHS, 2016). Furthermore, the percent of Kcals from fat, 13%, is only slightly higher than the national average contribution of fat, 12.6%, to the daily caloric intake (WHO, 2013; from FAO, 2007). Yet, both studies seem to underestimate potentially due to technical differences in the data.

Similarities appear in the comparison between food consumption in Rosendal and the municipality. Cereal and derived products contribute to the largest amount of Kcals in both diets. However, the contribution in Rosendal is not as noteworthy since the next highest contribution to Kcals is only one percent lower. Furthermore, cereals' contribution is lower than the municipality in terms of kilograms and caloric contribution. In addition, fat, dairy and egg, and meat consumption are 159.5%, 16.7% and 49.3% higher, respectively, in Rosendal than the average in Uppsala. That means fat is significantly higher in Rosendal than then municipality, and meat consumption is nearly double.

As seen in Table 7, a large amount of Kcal intake is from non-alcoholic beverages and fats. Both of these could be considered as empty calories. Since Russo et al. (2014) did not use non-alcoholic beverages in their analysis, it cannot be stated whether or not there is an increase in consumption. However, for fats, there is a significant increase in addition to increases in the demand for meat. These results could be due to differences that are seen among different demographic statuses such as socio-economic, age, and differences between urban and rural populations (Tilman & Clark, 2014).

These results follow the trends seen in other areas of the world. Guo et al. (2000) show a similar trend in China where urban populations, and higher income persons (typically in urban areas), have higher fat, meat and egg consumption compared to their rural counter parts. In addition, the same study shows a decline in cereal and staple crop consumption (Guo et al., 2000) and their contribution to nutritional energy to more animal products (Gerbens-Leenes et al., 2010) that is seen in the comparison between Rosendal and Uppsala municipality. Tilman and Clark (2014) also note this global trend and correlation between increases in food consumption with a higher environmental impact, higher income and urbanization as well as the consumption of empty and total calories seen in higher fat and caloric intake. However, an interesting trend is also seen in the increase of fruits and vegetables, not as noted in global trends.

In a comparable U.S. study, millennial students, who prefer vibrant, walkable neighborhoods and good access to public transportation, were encouraged by institutes of higher education to incorporate environmental responsibility into personal consumption (Schoolman et al., 2014). Schoolman et al. (2014) found weak commitment to sustainable consumption concerning how food is produced and consumed. Similarly, Rosendal is framed as a green, vibrant area with a walkable neighborhood and good access to public transportation (Uppsala Kommun, 2015b). In comparison, it is speculated that few in Rosendal consider the environment in their personal food consumption since only four participants indicate diet choices in consideration of the environment. While six participants structured their diet according to more ecological (organic) means of food consumption. If intuitions of higher education did not have an impact on sustainable consumption or commitment to environmental responsibility, as is the case in the U.S. study, and sustainability initiatives of policy, planners, architects do not consider the food system then the questions remains whether these initiatives will be able to influence change that is so desperately needed.

Emergy Synthesis

The emergy synthesis is used to interpret the environmental support, i.e. resources needed to support the current diets in Rosendal. The total emergy supporting food consumption in Rosendal is equivalent to 4.18E+15 seJ, nearly an order of magnitude higher than Uppsala. Based on the transformities, services have the highest energy quality. It is not unusual for services to be the highest or second highest contributor to purchased inputs, the second highest after meat in this case. In an emergy analysis of the Swedish food system, Johansson (2005) shows that indirect services largely support processing and distribution of purchased goods or imported inputs (76% and 85% of sector total, respectively).

In terms of total emergy, meat is conclusively the highest contributor. Previous studies also show that meat, in comparison to other food products, has the highest impact on the environment and GHG emissions (Scarborough et al., 2014; Tilman & Clark, 2014; Ranganathan et al., 2016; Springmann, Godfray, Rayner & Scarborough, 2016). Meat's emergy 'impact' is particularly evident when looking at the emergy of the food categories. It requires nearly three times the environmental support as the next highest—fish. The energy hierarchy can explain the emergy of meat. As seen in Table 1, protein foods have one of the highest transformities just above human services. Accordingly, it takes more environmental resources (e.g. food and water) and biological transformations to produce meat as well as additional emergy within the processing, packaging, distribution and marketing processes. When considering all the forms of energy and inputs in the processes necessary to produce the final product, as in a holistic systems approach, it becomes more evident how emergy accumulates into higher energy quality, and transformities, that create products with substantial amounts of embedded solar emergy.

Imported inputs have a significant contribution to the emergy of diets in Rosendal. They account for over 93% of all inputs whereas local, non-renewable (N) account for 5.5% and local, renewable inputs (R) only account for .99%. Therefore, relatively little local resources, both renewable and non-renewable, support the diets in Rosendal. This is shown in the low percent, 3.47%, of the system that is locally renewable. One way that R could be improved is through the installation of solar panels since it would decrease imported electricity. As such, additional emergy from electricity would move from F to R, which could impact the indices.

It is not surprising that the ELR ratio is high. In fact, ELR in Rosendal is higher than both the municipal and national average (Johansson, 2005; Russo et al., 2014). This is indicative of a system that places pressure on other systems through the need to continuously load or supply Rosendal with food, i.e. imported resources. As a result, the system is not considered sustainable, shown by the low ESI. The ESI also suggests that the system is vastly consumer-orientated and does not contribute to society without great environmental support.

Other indices and ratios show that diets in Rosendal are neither largely renewable nor self-reinforcing. If large investments (imported inputs) are needed to support the system then it becomes more challenging to generate feedbacks within the system. For example, food waste cannot be used as compost to grow food locally. Accordingly, it is considered a consumer system since it does not efficiently use local resources in Rosendal. Instead, it relies on the larger systems of Uppsala and globally to supply its food, water, energy and other crucial inputs such as kitchen appliances and indirect services. Yet, as considered in systems theory, there is no real consumption since most processes as in food preparation and consumption have both consumption and production. Therefore, it is both a producer and consumer due to transformations of emergy but the indices suggest more is consumed than produced.

Still, the system´s outputs or co-products consist of waste and urban life that have a UEV of 3.03E+10 seJ/g and 4.97E+11 seJ/hr, respectively. The output of urban life or human labor implies a high quality resource. This comes as a result of high resource throughput, reflected in the high UEV of 4.97E+11 seJ/hr. However, to support this urban lifestyle, the SCI, based on solar shares, shows that an average person in Rosendal appropriates two and a half times their fair global share of solar emergy. This is significant given it only considers food intake, and excludes all other household consumptions such as travel and other consumer goods, etc. This suggests that the UEVs generated in this study should be used with careful consideration in application to social life in other systems since this only includes the inputs used in food preparation and consumption. Furthermore, the high SCI could challenge the Uppsala's vision for 2050 where it hopes to develop within the planetary ecological limits (Uppsala Kommun, 2015a). In addition, if diets continue as they are now and consume more than their fair share, there may not be enough resources to adequately feed future populations (McLaughlin & Kinzelback, 2015).

In comparison to Russo et al. (2014), the differences between the total emergy of the municipality and Rosendal show a 12% increase in the amount of emergy needed to support a diet in Rosendal. The increase could be partly explained by the inclusion of the rural population in Russo et al.'s (2014) study. The relatively higher consumption of meat, fats, and dairy and eggs along with a decrease in the emergy of cereal in Rosendal could be explained by the higher impact, resource demand and consumption of these foods in the urban versus rural populations.

While neither system is sustainable or sourced locally, the difference in emergy clearly shows the additional resources needed to support such environmentally demanding, imported food. In a comparable study, Lin (2015) also shows that resources used for food consumption in Taiwan are much greater than the natural environment (renewable resources) can provide, particularly in highly urbanized areas. This implies vast shadow areas are necessary to support the urban lifestyle, which is also reflected in the high total emergy and SCI obtained in this study.

Still, there are some similarities seen between the diets in Rosendal and the municipal average. Both have approximately a 1.1 EYR and therefore do not efficiently use local resources. This also hold true to the national average of consumed foods, which is 1.21 (Johansson, 2005). The ELR for Rosendal is greater than the municipal by ~ 10 and national average by ~ 12. Consequently, Rosendal as a 'green' urban district places more stress on its system and is considered marginally less sustainable than both the municipal and national average.

While resource use in Rosendal will never be completely reduced, that does not mean the same function of the system, in this case urban life, cannot be provided in vastly different ways. This is a central aspect of systems theory which allows for the detection of alternative ways to reach the same output and assess which alternatives may be more efficient, renewable, sustainable, etc. As such, the indices and ratios in addition to the hypothetical scenarios do not aim to criticize the current system, but rather to identify particularly crucial points for improvement. Thereby, they provide the opportunity to explore alternative development paths that could deliver the same function in a more efficient and sustainable manner.

When looking at the scenarios, it shows the importance of renewable resources and obtaining resources locally. While the total emergy of both scenario A1 and A2 are higher than the vegetarian scenarios B1 and B2, the indices show that eating the same diet based locally is the most sustainable. Though the total emergy is higher, more emergy is fed back into the system as autocatalytic feedback, creating a higher rate of renewability. This is key to maximize empower and cultivate a self-reinforcing and self-organizing system. As discussed in the theory chapter, renewability and feedbacks facilitate the development of the most useful work from the inflowing (renewable) resources by reinforcing productive processes, overcoming limitations, and maximizing efficiency. Fresco (2009) also shows the importance of this in his definition of a sustainable food system. From this, it is possible to conceive that even if a portion of food is sourced locally, as indicated by the participants, the system's renewability and sustainability increases considerably. This is particularly noticeable in scenario A2, but also B2. Lagerberg Fogelberg (2013) similarly demonstrates the potential for locally produced inputs of a system, e.g. local feed used for the production of meat and dairy, to reduce impacts from these products and increase overall efficiency and renewability.

Although the indices show scenario A2 produces a more sustainable outcome, its SCI indicates that it is still insufficient when it comes to equality in food consumption and solar emergy when accounted for in emergy terms. Whereas, the vegetarian diets B1 and B2 have a lower overconsumption in terms of the SCI, and also show an increase in sustainability. This increase is even greater if a vegetarian diet is source locally. In addition, Weber and Matthews (2008) show that replacing one day's worth of red meat and dairy calories for a week of consuming chicken, fish, eggs or vegetables is more effective in reducing GHG emissions than buying locally for a week. While this contrasts the benefits of local foods shown in scenario A2, it supports the increased sustainability seen in scenarios B1 and B2. Thus, the results of this study in correlation to other factors suggest that reducing (red) meat consumption in combination while sourcing (more) food locally are key for future sustainable (urban) food systems. The challenge, as Springmann et al. (2016) outlines, is to find the right balance in reductions to meat consumption and the degree of adaption to a plant-based diet.

Still, it is interesting to consider that the current diet sourced locally is more renewable/sustainable than a vegetarian diet sourced locally. While both vegetarian scenarios have overall lower emergy, this changes the relative shares (%) of all input categories. In other words, the total emergy for food items decreases in these scenarios since meat and fish, some of the highest in terms of energy quality or UEV, are moved to fruits and vegetables. While, all other inputs remain constant, i.e. electricity, appliances, services, etc. This in turn gives a relatively larger F, even if R has increased in absolute number in scenario B2. This is because the total emergy in both B scenarios have a lower total emergy, which give less beneficial indices due to a lower output or productivity. This could be the most influencing factor as to why the vegetarian diets, particularly B2, are not as comparable to A2 in the indices.

This result could also be due to the assumption within the categorization of meat and fish products into the fruits and vegetables category. If all or a portion of meat and fish were add to dairy and eggs, the results could look different. A further explanation could be within the indices themselves. Since the some of the indices rely on other indices (e.g. ESI), any theoretical or methodological error within an initial index would be transferred to the new index.

However, when the EIR and EYR, which consider the balance between economic inputs to those from the environment, are considered in comparison with ELR and ESI, which highlight the importance of renewable resource use (Giannetti et al., 2010), the results and conclusions from this study become more clear. Since the EIR is high and there is little net contribution to society, then it is evident that more and more investments will be necessary in the long run since the system does not make use of emergy investment to generate autocatalytic processes, in this case grow food. Such a shift would transition the system from high throughput to a state where a larger share of the resources would be renewed internally, which, in the long run would reduce the need for constant external inputs. One way to create such processes is through the implementation of urban agriculture in Rosendal, using food waste and other inputs from the window of attention, as shown by Bergquist (2010).

Interview with Rosendal Fastigheter

Since the results from this study show that a more sustainable food system is one that produces (more) food locally, it is important to expand the focus to policy and planning, and simultaneously consider urban development and food production/consumption. In the interview with the main architect and a landscape architect, they indicated that there were not any explicit strategies to address food consumption (Architect, 2016; Intern Landscape Architect, 2016) When they designed the Smaragden apartment complex, they primarily focused on other environmental and social aspects of sustainability. While they included the opportunity to source a portion of their fruit and vegetable intake locally (berry bushes, planting beds and window farming), it was more to promote social sustainability and social relations among neighbors (ibid.).

Although food consumption was not an explicit strategy to affect food consumption, the decision to include berries suggests that food still holds some value in their definition, or conception, of sustainability. Though more symbolic than a systemic change, the fact that such experimentation with local food has already begun and their reaction and realization of the importance food has suggests that some architects and landscape architects may be increasingly receptive to adopt food aspects in urban development. In addition, the concept of window farming was influenced by an institute of higher education which suggests, in contrast to Schoolman et al. (2014), that institutes of higher education may play a role in encouraging persons interested in vibrant, walkable urban districts to incorporate environmental responsibility into personal consumption and even urban design. Despite having limited measures for food production, participants did not report growing food which indicates their efforts could be ineffective.

Therefore, food system aspects in urban planning, design and management appears in addition to outreach become increasingly vital when considering the resources necessary to support food consumption in Rosendal. Accordingly, if dietary changes are made in high-income countries such as Sweden (WWF, 2016) and high meat consuming areas such as urban environments (Tilman & Clark, 2014), more food currently imported to such areas could be distributed throughout the world. Such an argument is particularly supported by the inequitable solar share (SCI) in Rosendal. Based on the results of this study, if food systems were to be incorporated into local areas and emphasize low meat consumption, then it could be concluded that the sustainability of food consumption in urban environments could increase.

(De-) Limitations

Since all dietary assessments are not without flaw and it is difficult for participants to accurately estimate food intake, overestimations and underestimations in portion sizes could have occurred. Like other dietary assessments, 24-hour recall is prone to over- and under- estimation since it relies on the ability of participants to recall previous food consumption. This is also a possibility for the weekly estimations. Accordingly, the results from the dietary assessment may not represent actual food intake which could affect the results of the emergy synthesis. In addition, the exclusion of restaurants could have resulted in underestimations. This could also explain the price discrepancy between the participants' estimated monthly food budget and the calculated cost of food present in Tables 7 and 8. If more precise results are desired, many authors agree that using a measured dietary assessment improves the representation of food intake (e.g. Biró et al, 2002).

However, when compared to the food consumption represented in the weekly estimations, extrapolated to annual food intake, the numbers represented in the 24-hour recall are not an order of magnitude different than the weekly estimated food consumption. Still, the data from the 24-hour recall could be underestimated since all but one food category is lower in the 24-hour recall than the participants' weekly estimations. Likewise, the weekly estimations could be overestimates for the same reasoning. Furthermore, extrapolating data from 24-hour recall and week estimations could have an impact on estimated food consumption in Rosendal. Nonetheless, Block (1982) indicates that the 24-hour recall adequately characterizes the average intake of a group, in this case 33 unique individuals. Considering the number of participants, the data my not be representative of the entire Rosendal population. However, the mean of both dietary recalls is used and assumed to balance the likelihood of over- and under- reporting.

Furthermore, not all demographic groups are represented equally, and the food consumption gathered for residents in Rosendal may be more indicative of a younger demographic of people. Additionally, the definition of local as food produced in Sweden could have implications for the percent of food consumption that the participants estimate to be local. Since it is ambiguous whether the origin of products produced by Swedish companies is indeed from Sweden, the estimations based on products produced in Sweden could have lead to overestimations. Therefore, estimates of local foods are only used for hypothetical scenarios.

Other assumptions that could affect the results were used in the labeling of food categories and emergy synthesis. For example, Russo et al. (2014) had not assessed sugar intake as was done in the questionnaires for this study. Therefore, it is assumed that sugars were included in the category for cereals and derived. In addition, to calculate for the physical area it is assumed all flats are the same size, the average indicated by the participants. In addition, all stimulants are assumed to be coffee. Both coffee and alcoholic beverages include water, although it is a minimal amount, there could be some double counting. Accordingly, a 5% and 10% error check was done. While the absolute numbers may not be correct, neither the 5% nor 10% error check showed that results were significantly altered or an order of magnitude difference for food consumption and emergy synthesis results. In addition, the UEVs may not represent the emergy of all food products since some are context dependent and the food consumed in this study may not have been from the locations where the UEVs were generated. Still, it is believed the data and results of the study are a valid representation of where food consumption currently stands in a green, urban district such as Rosendal.

7 Conclusion

The results of this study contribute two new UEVs generated from the emergy synthesis and provide an understanding of where Rosendal, as a green urban district, stands in terms of food system sustainability. The significant environmental support to residents' food consumption in Rosendal shows that it is important to consider food consumption when assessing the sustainability of urban systems. The results show that the environmental support to food consumption in Rosendal is even greater than and less sustainable than the municipal average. To improve the sustainability in Rosendal, the indices and hypothetical scenarios indicate that it is important to source more foods locally as well as reduce the consumption of (red) meat and other resource demanding foods. Furthermore, the architects in Rosendal reveal that they do not have any explicitly strategies for food. However, the inclusion of berry bushes into their design shows that food holds value in their conception of sustainability. Therefore, this study concludes that food consumption should be considered from a more holistic perspective that integrates food production policies into urban planning, design and management that support the growth of local foods.

A holistic systems approach is indispensable when considering the impacts of food consumption since it can detect different ways to deliver the same output while evaluating what alternative may be more efficient, renewable and sustainable. To holistically examine whether an urban district is sustainable from a systems theoretical approach, humans and their food consumption cannot be excluded because they are embedded into and affect the larger system through various processes or interactions occurring within the systems. As such, food consumption is a subsystem within the greater urban and global food system. The interactions between these systems are especially important to consider when food consumption in a 'green' urban district is unsustainable as demonstrated in this study. Furthermore, general systems theory states one level of a system contributes something that the previous system could not, which suggests that there are issues that need to be addressed in the larger scales. Therefore, to achieve truly sustainable urban districts, it is pertinent to consider the environmental support needed for the total emergy of the inputs of that system.

Because food is such an essential part of our lives, it is important to consider food consumption (demand) and how it impacts food production (supply). Accordingly, new models of production and consumption are needed for a resilient, sustainable food system that is capable of absorbing and recovering from shocks yet supply enough food for a growing (urban) population. Therefore, the opportunity to grow local foods should be implemented into urban planning, design, and management especially if current development is to make a substantial contribution to sustainability as is often claimed in policies and planning for sustainable (urban) development. Although many urban planners and architects have started to address aspects of urban food to some extent, this study demonstrates that is questionable whether urban development can ever become sustainable before holistically considering urbanization in relation to the current food system, among other challenges facing cities today.

Suggestions for future research then include evaluating aspects of food production in urban centers. Further studies could look into alternative food systems such as true examples of the hypothetical examples shown in this study. Additional investigations into the sustainability of food consumption based off of, at least to some degree, local urban gardening could benefit the future of urban food production. Studies that examine policies that are effective in promoting and developing more sustainable food systems are also suggested. In addition, further studies could develop a framework for urban developers, planners and designers to work together in creating urban centers and districts that are better able to self-organize and increase the renewability of the emergy they consume. Achieving sustainable urban development and urban food systems is a complex task with many different aspects to consider and investigate. Therefore, it is important to consider urban studies from a holistic approach that incorporates various fields of study.

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Appendix 1

Participant: ____

Sustainability in Rosendal

Dear Respondent,

Thank you for agreeing to participate in this important survey on lifestyle patterns! Your contribution will provide information for understanding how residents live in Rosendal and how it affects the area's sustainability.

In this study, we will summarize your food consumption including how much and what. This survey also includes transportation issues and other consumption. It should take approximately 20 minutes to complete. Please do your best to answer the questions as accurately as possible, and be assured that your answers will be kept in the strictest *confidentiality*.

Demographics:

Name:

Gender:

Age:

Occupation:

Address/building name/tenant or similar:

Time living in Rosendal:

Contact Information:

May we contact you for missing information?

Level of education:

Household size (m^2 and people in household):

Reason for moving to Rosendal:

General Questions:

1) Have any of your habits/practices changed since moving to Rosendal? If yes, how? (Eating habits, consumption, commuting, transport, change of businesses, etc.)

____

____

____

____

2) How much do you spend on hygiene and cleaning items every month (average SEK/month)?

____

3) How far do you commute? (Daily average in kilometers).

- Walk ______________________________
- Bike _______________________________
- Car ________________________________
- Bus/public transit ______________________

4) How often do you travel (long distance)? Where? Reason? Mode of transportation?

____

____

____

____

5) Please list the number and type of electric appliances in the household (e.g. TV, laptop, tablet, microwave oven, toaster, etc.).

____

____

____

____

6) Do you own any other type of equipment, such as tools or sports equipment? What? Average cost per item?

____

____

____

Food Consumption Questionnaire

Instructions: As accurately as possible, please indicate the amount of the foods **you** consumed **yesterday** in **Table 1**. In **Table 2**, please **estimate** the **average** amount of food you eat in a **week**. For each table, please estimate the percentage of food that is **organic** or **locally** produced (from Sweden). The products can be both, but please note these percentages separately.

Table 1. *Food consumption of a 24-hour period measured in grams (g) and milliliters (ml), listing the percentage of organic and local food consumed yesterday.*

Meal type Breakfast, lunch, dinner	**Time**	**Place**	**Food** Food item, drink and other food	**Amount** (g/ml)
Percent organic:			**Percent local:**	

Reflecting on your food consumption from yesterday, was your food consumption **different** than the typical day? If it was different, please indicate why and in what way?

( ) Yes Comment:____

( ) No

Table 2. *Average food consumption of a typical week measured in kilograms (kg) or liters (L), listing the average percent of organic and local food consumed in a week.*

	Week	**Percentage**	
Food Commodity	**Quantity** (kg/L)	**Organic**	**Local**
Cereals and grains (bread, pasta, flour etc.)			
Starchy vegetables (potatoes, roots, etc.)			
Vegetables			
Pulses (legumes, beans, etc.)			
Fruits and berries			
Meat (all except fish)			
Fish and seafood			
Dairy Products (cheese, milk, yogurt, etc.)			
Eggs			
Oils and fats (vegetable and animal fats, nuts)			
Sweets (i.e. sugar, syrups, candy)			
Stimulants (coffee, tea, cacao)			
Beverages			
Non-alcoholic			
Alcoholic			
Not otherwise specified			

Time spent cooking (hours/***week***): _____________________

Food wasted (per ***week***) % or volume: ____________________

How often do you eat out at a restaurant (times/***month***): __________________

Amount spent on food (SEK/***month***/*person*): ___________________

Comments:

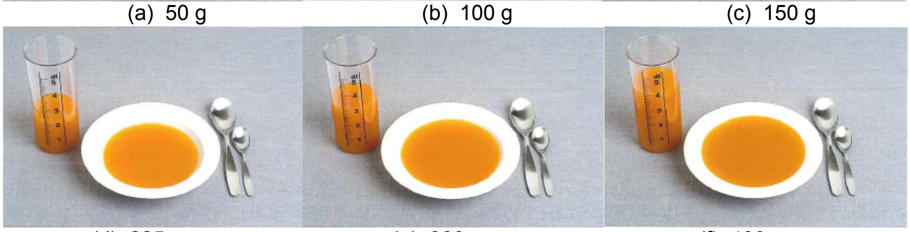
Thank you for choosing to participate!

Appendix 2

Food Portions Guide[5]

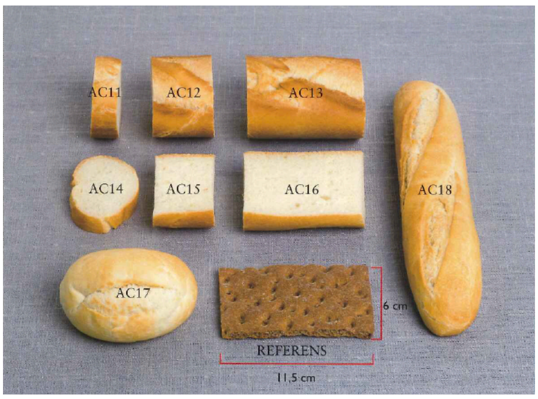
Soup / Drink

(a) 50 g (b) 100 g (c) 150 g



(d) 225 g (e) 300 g (f) 400 g

Baguette / Bread



AC11: 12 g	AC12: 30 g
AC13: 60 g	AC14: 6 g
AC15: 15 g	AC16: 30 g
AC17: 50 g	AC18: 135 g

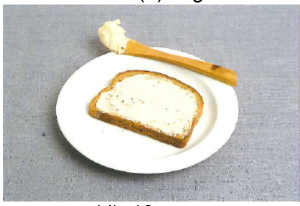
[5] Edited from Livsmedelsverket (2009).

Butter / Bread topping


(a) 3 g


(b) 5 g


(c) 7 g

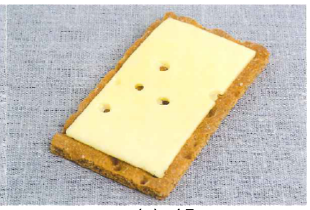

(d) 10 g

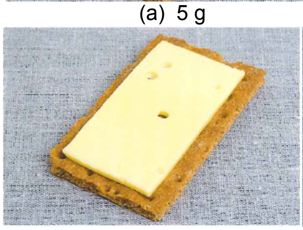

(e) 15 g

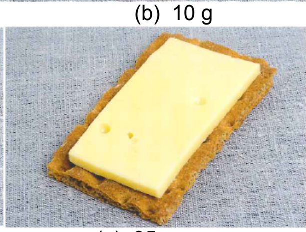
Cheese

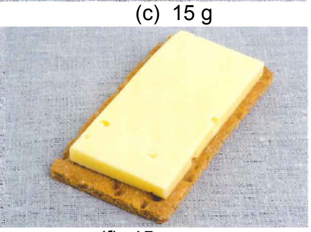

(a) 5 g


(b) 10 g


(c) 15 g


(d) 20 g


(e) 35 g

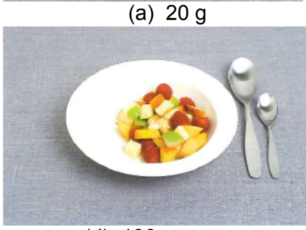

(f) 45 g

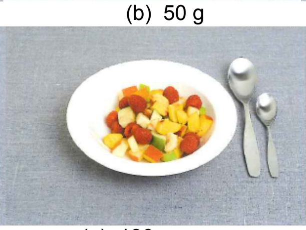
Fruit / Berries

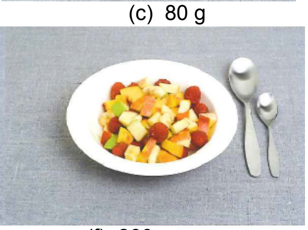

(a) 20 g


(b) 50 g


(c) 80 g


(d) 130 g


(e) 180 g


(f) 260 g

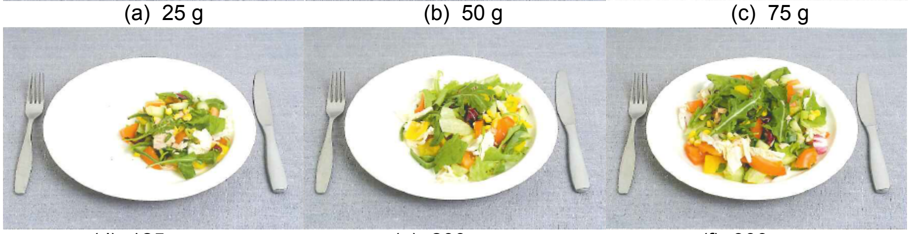
Oats / Rice / Grain

(a) 50 g (b) 100 g (c) 150 g

(d) 225 g (e) 300 g (f) 400 g

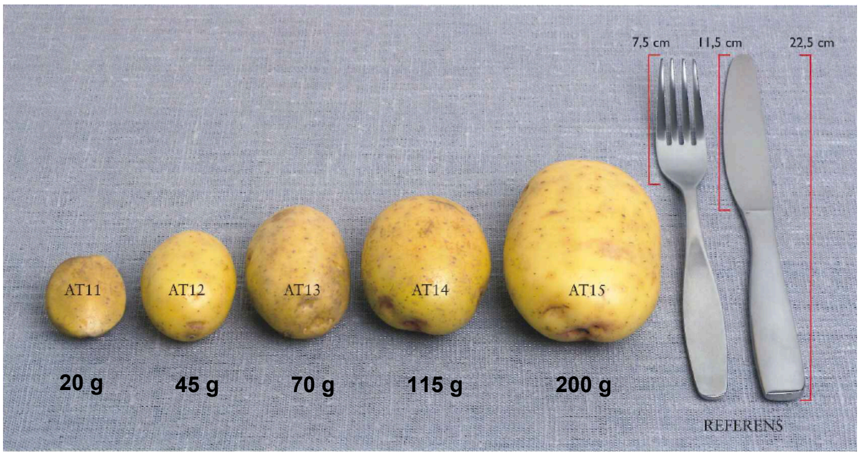
Salad

(a) 25 g (b) 50 g (c) 75 g

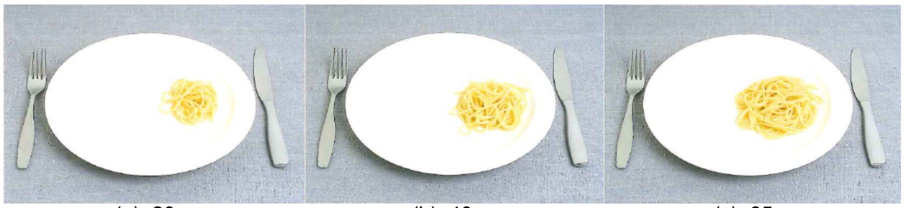


(d) 125 g (e) 200 g (f) 300 g

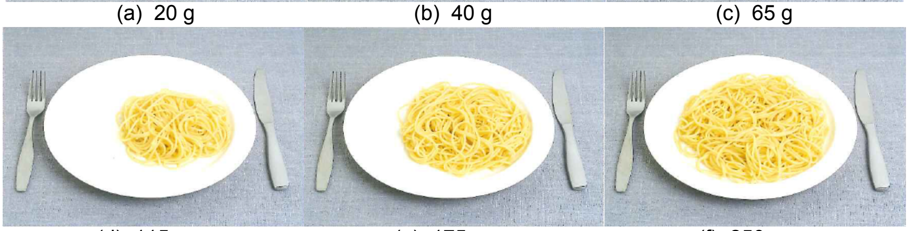
Potatoes



Pasta

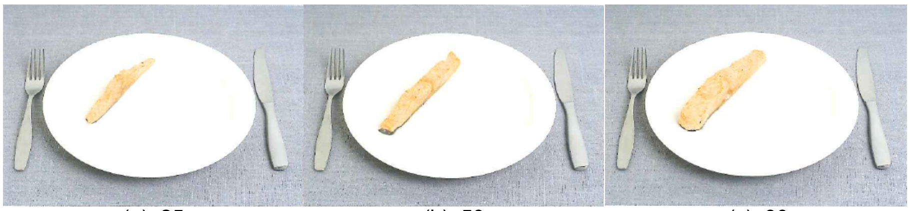


(a) 20 g (b) 40 g (c) 65 g

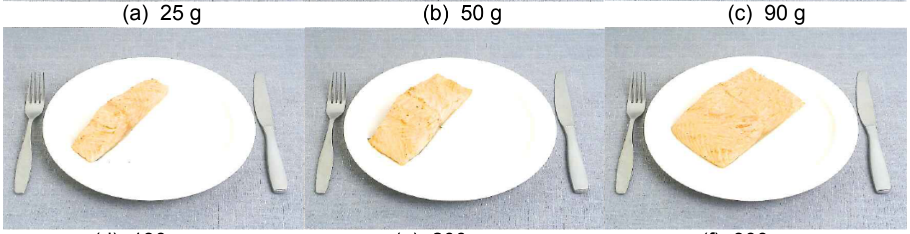


(d) 115 g (e) 175 g (f) 250 g

Fish / Salmon

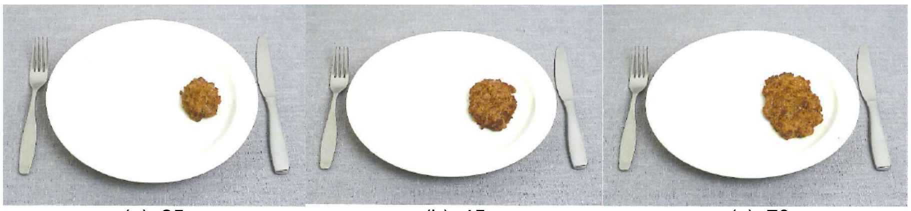


(a) 25 g (b) 50 g (c) 90 g

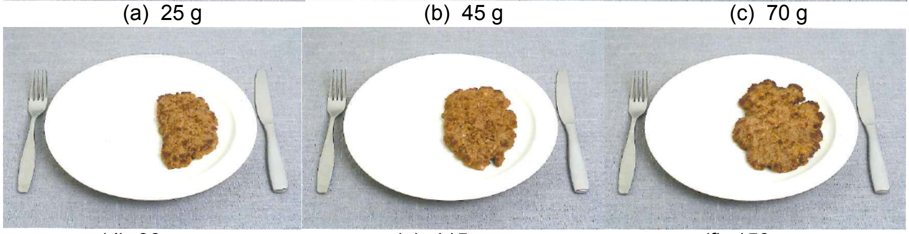


(d) 130 g (e) 200 g (f) 300 g

Beef



(a) 25 g (b) 45 g (c) 70 g



(d) 90 g (e) 115 g (f) 150 g

Photos and weights are edited from Livsmedelverket (2009).

Appendix 3

Emergy Table 10 Footnotes and calculations:

a. All UEVs are updated to the new global baseline proposed by Brown and Ulgiati (2016).
   a. Found UEV using NEAD database and reviewing the original papers when needed.

Local renewable inputs (R)

1. Sun received in the area of Rosendal per year (Avg. Total Annual Insolation J/yr)(Area)(1-albedo)(UEV) = 3.61E+09 [J/m^2/yr] (NASAeosweb, 2016) x 5.31E+00 [m^2] (this study) x 0.15 (NASAeoseb, 2011) x 1 [SeJ/J] (Odum, 1996).
2. Water input used in the area of Rosendal assumed as renewable for food consumption (i.e. cooking, washing) per year per capita (volume of water)(the density)(joules per kilogram of water)(UEV) = (40 x 365)/1000 [m^3/yr] (http://www.svensktvatten.se/; FAO, 2011a) x 1000 [kg/m^3] x 4990 [J/kg] x 5.67E+05 (Russo et al., 2014).

Local nonrenewable inputs (N)

3. Physical structure used for cooking (the mean hours spent cooking)(UEV-emergy of living in an apartment per hour) = (6.79 hrs/week x 52 weeks) (this study) x 6.51E+11 SeJ/hr (updated from Puliselli et al., 2011 and converted from yearly to hourly by dividing UEV by number of hours in a year 8760)

Imported inputs

4. Electricity used annually for cooking ((((mean kwh for kitchen appliances)(time spent cooking)+(energy use fridge-freezer)+(energy use dishwasher)) (joules per kwh)) / (mean number of residence per apartment))(UEV) = ((((8.17E-01 kwh (Göteborg, 2016) x 6.79 hr/week (this study)) + 233 kwh/yr (Electrolux, 2016) + 241 kwh/yr (Electrolux, 2016) x 36000000 (Rapidtables.com))/2.2 (this study)) x 1.72E+05 SeJ/J (Russo et al., 2014)..
5. Non-alcoholic beverages consumed per year (annual quantity, juice concentrate)(Kcal/liter)(joules/Kcal)(UEV [farm to gate]) = ((9.02 x 12)/5) liters, concentrate (this study) x 1,648 Kcal/liter (Swedish Food Database) x 4184 J/Kcal (Rapidtables.com) x 2.29E+05 SeJ/J (Fernandez Pereira & Ortega, 2004).
6. Stimulants consumed per year (Quantity[g]/yr., dry weight)(UEV [farm to gate]) = 4.89E+06 g (this study) x 7.28E+05 SeJ/g (Cuadra & Rydberg, 2006).
7. Cereals and derived consumed per year (Quantity[g]/yr.)(UEV) = 1.00E+05 g (this study) x 4.17E+08 SeJ/g (Russo et al., 2014).
8. Fruits and vegetables consumed per year (Quantity[g]/yr.)(UEV) = 1.56E+05 g (this study) x 4.91E+08 SeJ/g (Russo et al., 2014).
9. Dairy and eggs consumed per year (Quantity[g]/yr.)(UEV) = 9.54E+04 g (this study) x 1.06E+09 SeJ/g (Russo et al., 2014).
10. Alcoholic beverages consumed per year (Quantity[g]/yr.)(UEV) = 3.94E+04 g (this study) x 1.10E+09 SeJ/g (Russo et al., 2014)
11. Appliances used per year (((Operating hours)/(Product lifetime-assumed 10 years)(Weight))/(Average number of residents per apartment))(UEV) = (((3.53E+02 hrs/yr (this study) / (8.77E+04 hrs x 1.85E+05 g (Electrolux, 2016)) / 2.2 resident/apartment (this study)) x 5.23E+09 SeJ/g (Brown, 2001).

12. . Fats consumed per year (Quantity[g]/yr.)(UEV) = 1.30E+04 g (this study) x 1.95E+10 (Russo et al., 2014)
13. Fish consumed per year (Quantity[g]/yr.)(UEV) = 1.52E+04 (this study) x 3.38E+10 (Russo et al., 2014)
14. Meat consumed per year (Quantity[g]/yr.)(UEV) = 4.12E+04 (this study) x 3.73E+10 (Russo et al., 2014)
15. Services used per year ((Money spent on stimulants/yr. + money spent on non-alcoholic beverages/yr) + ((Money spent on appliances / lifespan of ten years) / mean number of residents per apartment))(UEV) = ((135 SEK/yr. (this study) + 38 SEK/yr. (this study)) + ((28357 SEK (Electrolux, 2016) / 10 yr. (assumed lifespan)) / 2.2 residents (this study))) x 3.35 SeJ/SEK (Russo et al., 2014)

Total emergy input (Y) is the sum of inputs two (water) through fifteen (services) represented in SeJ. One (sun) is not included to avoided double counting sun in water.

Outputs

16. Including services
    a. Waste (average waste in grams/week)(Number of weeks in a year) = 2650 g/wk. (this study) x 52 wk./yr.
        i. UEV (Y) / (Units[g]/yr.) = 4.18E+15 SeJ / 1.38 g/yr. (this study)
    b. Urban life (Hours/yr.)-(hours spent cooking/yr.) = (24 x 365) – (6.79 hrs./wk. (this study) x 52)
        i. UEV (Y) / (Units[hrs.]/yr.) = 4.18E+15 SeJ / 8.41 hrs./yr.
17. Excluding Services
    a. Waste (average waste in grams/week)(Number of weeks in a year) = 2650 g/wk. (this study) x 52 wk./yr.
        i. UEV (Y - Services) / (Units[g]/yr.) = (4.18E+15 SeJ – 1.13E+15) / 1.38 g/yr. (this study)
    b. Urban life (Hours/yr.)-(hours spent cooking/yr.) = (24 x 365) – (6.79 hrs./wk. (this study) x 52)
        i. UEV (Y - Services) / (Units[hrs.]/yr.) = (4.18E+15 SeJ – 1.13+E15 SeJ) / 8.41 hrs./yr.

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n. Brown and Bardi, 2001.
o. Vattenfall, 2016.
p. Puliselli et al., 2007.
q. Buenfil, 2001.
r. RapidTables, 2016. http://www.rapidtables.com
s. FAO, 2011a.
t. Hussein, 2016.