DEGREE PROJECT IN URBAN AND REGIONAL PLANNING, ADVANCED CYCLE
STOCKHOLM, SWEDEN 2014

Cohousing and resource use

A case study of the Färdknäppen cohouse

FREDRIK SUNDBERG

SoM EX 2014-31

KUNGLIGA TEKNISKA HÖGSKOLAN
SCHOOL OF ARCHITECTURE AND THE BUILT ENVIRONMENT
Department of Urban Planning and Environment
Division of Urban and Regional Studies

Abstract

In relation to the contemporary discussion about sustainable housing, this thesis investigates cohousing from a resource use perspective. Cohousing is a type of housing is based on the idea of sharing space and domestic work, while still having the privacy that a private apartment gives. The sharing of meals, space and things that is common in cohouses is often believed to save resources, and this thesis makes use of a case study in the cohouse Färdknäppen in Stockholm. To evaluate the resource use, system analysis has been used. System analysis is commonly used to analyze the environmental impact from goods or services, but not so commonly on housing in the way this study uses it. More exactly, the system analysis studied the resources used to provide housing for one person during one year, which included shelter, but also other things normally associated with a home such as meals. Results showed that the sharing of meals does not result in less consumption of food, and that sharing of things saves resources to a relatively small extent. Still, by living in Färdknäppen, a person can save as much a ton of greenhouse gas-emission per year compared to the average. This substantial save mainly comes from less use of both heating- and electric energy, which in turn results from the way the cohouse is working. The communal cooking is believed to save electricity and the sharing of space allows resident to live with less floor space in total which saves energy for heating and electricity. There is also a potential to further lower resource use by changing the diet and to live with even less floor space that could be utilized in a cohouse, as well as in conventional homes.

Acknowledgements

This master thesis is the final work during a five year engineering education in sustainable urban planning and design at the Royal Institute of Technology in Stockholm. The work is worth 30 credits and was written during the spring of 2014 at Ecoloop AB and at the Royal institute of Technology.

I would like to thank the following persons for giving good advice and contributing to this work:

-Moa Tunström, supervisor at KTH

-Bo Svedberg, supervisor at Ecoloop AB

-Simon Magnusson, supervisor at Ecoloop AB

-Mette Kjörstad and other residents in Färdknäppen who willingly invited me to the cohouse and answered my questions.

Table of content

1 Introduction

1.1 Background and context

Sustainable urban development is more and more frequently discussed. Several large urban development projects in Stockholm and elsewhere the last and coming years have had and will have a clearly green profile. The discussion in such cases often tend to focus on the physical environment; buildings and physical infrastructure, and how it contributes to sustainable districts, but less on the environmental impact caused by residents' lifestyle and behavior. At the same time, there are many indications that this factor might influence a city's overall environmental impact a lot, maybe even more than the technical standard of people's homes (One Tonne Life, 2011; Sanne, 2012; Wangel, 2013). This is good to have in mind while discussing sustainable urban development, and to view a home not only in terms of its physical form. Wangel (2013, p. 19) states that "…technologies and concepts are not neutral, they bring norms, values and lifestyles.", which also applies on housing. Different types of housing bring different lifestyles with different potential for sustainability. A life in a suburb far from the city center with bad access to public transport can differ a lot compared to living in a central district in a multifamily house, for instance. Or, living in a spacious penthouse differs a lot from living in a cohouse, for that matter. Departing from this, this study seeks to investigate the link between housing types and sustainability further. It does so by studying cohousing from an environmental point of view, since cohousing is an unconventional type of housing that is often put forward as a more sustainable form of living than more a conventional home. At the same time, this is something that has not been researched a lot, which makes it even more interesting to investigate further.

1.2 Purpose and research question

The purpose of the study is to investigate whether the environmental impact from cohousing differ from the environmental impact of regular housing. Another purpose is to assess if the system analysis-approach is useful in order to do this, and if the approach has a potential to be used for assessment of other housing-types environmental impacts. To fulfill the purpose, the following questions are asked:

- How does resource use in a cohouse differ compared to in a corresponding average home in Sweden and to what extent can potential differences be related to the type of housing?
- How well does the system analysis approach work for assessing environmental impact from a household?

1.3 Goal

The goal is to be able to show if cohousing is saving resources by enabling residents to live more resource efficient than what people living in conventional homes do. In this way, the study tries to present an alternative approach to what a resource efficient home are, in relation to research concerned with for example passive houses and smart homes. The target group for this thesis is actors involved in planning of residential areas who may need knowledge about sustainable housing and resource saving potentials.

2 Methodology

2.1 Case study

The main part of this work is a case study, done in the cohouse Färdknäppen in Stockholm, Sweden. A case study can, according to Groat & Wang (2002), best be described as a conceptual container that can house various research approaches. A case study is "an empirical enquiry that investigates a phenomenon or setting" (Groat & Wang, 2002, p. 346). Typical characteristics of a case study are often that the case study focuses on one or more objects in their real world context. Context here means both historical and contemporary circumstances leading to the studied phenomenon or object, and an advantage with a case study is when the object or phenomenon is studied in relation to these.

Another characteristic of a case study is the importance of theory development in the design phase, regardless if the purpose is to test or develop theories. A theory however does not have to be a "grand theory", but a theory of what is being studied, than can be tested in the case study (Groat & Wang, 2002, p. 352). In other contexts, theory development of this kind could mean hypothesis. The idea is that the theory is raising new questions and hopefully answers, that leads to further theory development and potentially an ability to generalize back to the literature (Groat & Wang, 2002). A general critique is that this cannot be done from case studies, but other argue that this is a general problem with for instance experiments as well, and that a case study is no worse than any other methods (Groat & Wang, 2002). But, it is important to generalize from the right things, and keep case-specific factors to the case study, which otherwise might lose uniqueness (Groat & Wang, 2002).

A case study also often uses multiple sources of evidence in order to create triangulation of results. One type of such multiple evidence can be other similar case studies; another type is different data sources for the same thing, such as using a combination of archives and oral history. A case study can be based on either qualitative data, quantitative data or a combination of both, according to Groat & Wang (2002).

2.2 Literature review

As discussed by Groat & Wang (2002), context is important in a case study, and in this thesis, a literature review serves as a base to describe this context. According to Groat & Wang (2002), a literature review is a type of exploratory system that builds on an annotated bibliography but with more carefully selected references that tells a story. It needs an introductory statement, telling what the intend of the review is, a summary of the general theme that serves as the base for the further work in the research and observations in the literature on what is missing, which is the base for further research. Sometimes, there are different opinions on different matters in the literature, which also can serve as a base for research on what seems to be the most accurate among contradicting theories (Groat & Wang, 2002). The literature review has mainly been used as a base for the theory section and a few sources are a bit more central than others. One is the book "Living together - Cohousing Ideas and Realities Around the World", which is an edited collection written after an international cohousing conference held in Stockholm in 2009, edited by Dick Urban Vestbro, researcher at the Royal Institute of Technology in Stockholm. Vestbro is a central person in research about cohousing, and also lives in a cohouse in Stockholm himself. Another central source is the ILCD handbook, which is a guide for life cycle analysis, published by the European Commission, Joint Research Centre, & Institute for Environment and Sustainability (2010). This book is very detailed, and discusses most aspects of LCA's.

When there are contradicting opinions, this can also help to get a picture of a "conceptual landscape" (Groat & Wang, 2002, p. 58). Such a conceptual landscape often has a central "buzz-word", such as "sustainability", which might have a wide variety of meanings for different people or actors (Groat & Wang, 2002). Common is that "many have bought into [a concept], but far fewer people can actually define [it]" (Groat & Wang, 2002, p. 59). In such cases, these words will have a variety of meanings and it could be useful to try to outline different approaches to a concept. In this thesis, sustainability and its derivative are examples of this, and while few argues against sustainability, there are several views on what is sustainable or what is a sustainable lifestyle, for instance.

2.3 Epistemological approach

Wyly (2011) discuss positivism and its related, often quantitative, methods. Considering the quantitative character of this thesis, it is interesting to discuss his approach, which I find useful when choosing and arguing for the methods used. Wyly argues that positivism has a bad reputation based on the use and application of ideas originating from positivist research in the 1960s. Wyly therefore tries to separate "positivism" and what he calls the "positivist city hall" (2011).

> The [positivist city] machine is built on a powerful triumvirate of (1) epistemological pretentions of objectivity, rationality, universality and incontrovertible certainty; (2) methodological worship of mathematical logic and quantitative sophistication; and (3) political acquiescence to or support for conservative, hierarchical forms of power and coercion. All radical urbanists agree that this positivist city machine must be destroyed, even if they cannot agree on exactly what should replace it.
> (Wyly, 2011, p. 893).

Based on this, Wyly argues that positivism has an undeserved bad reputation, because it is commonly mistaken for alone causing in a kind of urban planning that could not have happened without the state-centric policy makers in the "positivist city hall". Wyly therefore argues that is wrong to instinctively reject positivism on those premises, because it will leave the field open for conservative powers to define positivism while it has the potential of being a powerful tool for progressive forces. As an example of such a field of research that could be considered progressive, at least in relation to the powerful forces disagreeing with it, Wyly brings up global warming and cites (the mainly non-positivist) Latour: "Why does it burn my tongue to say that global warming is a fact whether you like it or not?" (quoted in Wyly 2011, p. 894).

With this being only one example of fields were positivism can do good, Wyly calls for a "radical positivism". This positivism does not claim to have a "perfect, objective observation of the real world" (Wyly, 2011, p. 908). Rather, it is "a modest and progressive positivism [that] works in partnership with nonpositivist projects to imagine and observe new urban worlds that *could be made real.*" (Wyly, 2011, p. 908). The radical positivism Wyly argues for admits that practices or methods might be social constructions, but that cannot be the end conclusion. Instead it must be the starting point for the making of "better urban worlds", in Wyly's words (2011, p. 908). This standpoint is typical for "Positivists and their intellectual descendants", who commonly view theories as instruments for explaining but not as true representations (Sismondo, 2010, p. 7).

The use of quantitative methods in this thesis should be seen from this perspective, and while the method used does not necessarily show a true reality, they are a pragmatic tool to assess environmental impacts from human activity. As Latour (cited above) states, global warming seems to be a fact, and a suitable approach for doing research related to it (which this study can be said to be) might be the radical positivist approach that Wyly proposes, or at least be inspired from it. This also goes back to what Groat & Wang (2002) discuss; the method needs to suit the theory. If the theory in this thesis is concerned with whether residents living in cohousing have a smaller environmental impact than an average person, one suitable method to test this is life cycle analysis.

2.4 System analysis

As mentioned, a case study is mainly a container for different research approaches and in this case, the main approach in the case study is system analysis. According to Finnveden & Moberg (2005), system analysis can be described as an approach, rather than a method, and a way to look at problems (Finnveden & Moberg, 2005). When it comes to calculating environmental impact from various processes or actions in more absolute terms, system analysis is a common approach, and it was chosen in this study since it was considered being a good approach to answering the research question. Groat & Wang (2002) states the perhaps obvious: "there are usually ´good fits´ between the theory and the research strategy chosen to test it" (Groat & Wang, 2002, p. 75). As an example, they bring up Einstein's relativity theory, which would be hard to test with qualitative methods.

System analysis can be performed in many ways, and to choose a more specific method, a comparison-chart with different system analysis tools' attributes was created based on the review of system analysis tools by Finnveden & Moberg (2005). Groat & Wang (2002) describes a method as a measuring instrument, and to get an appropriate result, the right methods needs to be chosen. The comparison was done in order to do so. It turned out that LCA, Life Cycle Analysis (or -Assessment) was most suitable, because the scale of the analysis was suitable for a building or an individual, and the timeframe allows it to be done both to evaluate a past or present activity as well as modeling future impacts (Finnveden & Moberg, 2005). It is also one of the more commonly used types of system analysis, which means that there is good documentation on how to do it. The principle has been to use parts of the LCA methodology to compare resource use in the cohouse in the case study with an average-alternative which is basically an average household in conventional housing, constructed to correspond to the cohouse in the case study. The "average alternative" is discussed further in section 4.5.

It is important to note that this study will only use certain elements of the LCA-methodology. The study is mainly limited to greenhouse gases and phosphorus. There are many other aspects to environmental efficiency, such as scarce resources or toxic materials, but those are not taken into account here. As the study is done, it is also not primarily aimed at assessing an absolute environmental impact from residents in cohousing, but rather to estimate a relative environmental impact from residents in cohousing in relation to residents living in regular housing.

2.4.1 Life Cycle Analysis

The main purpose with the system analysis is to estimate environmental impact from the Färdknäppen cohouse, in relation to conventional housing. To do this, this study makes use of parts of the LCA-methodology. LCA stands for Life Cycle Analysis or Assessment, and is commonly used to assess and compare environmental impacts from production or services (Finnveden & Moberg, 2005). In the following section, system analysis and LCA will be discussed further, and specifically the so called LCI (life cycle inventory) that is the part of a full LCA where environmental impacts from different processes and activities are compiled.

The basic principle with a life cycle analysis is to look at the environmental impact of a product during its whole lifecycle, from cradle to grave or sometimes even from cradle to cradle. This is based on the system analysis perspective, and the idea is that a more adequate assessment can be made if a holistic approach is taken (Finnveden & Moberg, 2005). For instance, if looking solely at the use phase of a new product, it might have very low environmental impact. It might then be compelling to replace an old product with a new product, to increase the environmental efficiency. The idea with the life cycle analysis is to avoid this, and include production and extraction of materials and disposal of a product and recycling of the materials it is made from. With this perspective that includes environmental impact from the whole lifecycle of a product, it might appear as a better alternative to keep an existing inefficient product, because replacing it will require more resources and have a bigger environmental impact. It is important to note that this type of analysis can be done on other things than products, such as on services, which housing can be seen as (Finnveden & Moberg, 2005).

Even though it is common with flow charts picturing the several steps in a LCA, it is important to understand that it is not a completely linear process. Flow charts gives guidance, but in reality the process is iterative and steps often need to be revised during the process, as new information comes to light (European Commission et al., 2010). During a second or third iteration, everything from data sources to system boundaries can be revised if new information indicates that it might be necessary. The same applies if it is discovered that certain information cannot be obtained, which might cause a need to limit the scope further (European Commission et al., 2010, p. 28). In such cases, but also during the rest of the work process, it is important to document why certain decisions were made. Even though the report is the last thing that is done in a LCA or LCI, continuous notes during the whole process is the basis for a thorough report (European Commission et al., 2010).

2.4.2 Scope

The scope is dependent on the goal of the study (European Commission et al., 2010). An early decision that needs to be done is what type of deliverable the study will result in. It can for instance be a complete LCA in accordance with the ISO-standardization, or just parts of it. For instance, for some purposes it could be enough to make a LCI, a Life Cycle Inventory, which is a part of a full LCA. I such cases, the steps in the LCA where the results from the LCI are weighted or divided into impact categories are left out. The important thing is that it matches the goal and intended use for the study (European Commission et al., 2010). If the purpose is to monitor the environmental impact from a specific industry sector or product group, a full LCA can be left out and the LCI might be enough (European Commission et al., 2010).

2.4.3 Functional unit

Central to LCA is that it focuses on the function provided by a product or service, rather than on the system itself. As an example of such focus, European Commission et al. mentions “covering an outdoor wall against the weather” as the sought after function, called “functional unit” (2010, p. 60). Obviously, there are several solutions that provide this functionality, for instance steel sheeting or paint. It is then important to not compare steel sheeting to paint based on what has the least environmental impact for, say, 1 kg of material. Instead, the LCA should consider which one of the solutions that does provide the functionality stated in the functional unit, which might mean that 5 kg of steel sheeting is required to do same job as 0,5 kg of paint, but on the other hand the steel sheeting might last longer (European Commission et al., 2010). European Commission et al. suggest that the functional unit should answer the questions “what”, “how much”, “how well” and “for how long” (2010, p. 60). Continuing with the previous example, this would mean that it could be a good idea to specify the function unit further, into something like "Complete coverage of 1 m2 primed outdoor wall for 10 years at 99.9 % opacity" (European Commission et al., 2010, p. 60).

Having defined the functional unit, the next step is to detail a reference flow. In the case with protecting an outdoor wall, the reference flow could be paint or metal sheeting in quantities that delivers what is stated as the functional unit (European Commission et al., 2010).

European Commission et al. (2010) distinguishes between qualitative and quantitative aspects of a functional unit. Quantitative aspects of functional unit could be that it is important to choose a functional unit that does take intensity of use into account. A car can for instance be used every day or just a couple of times per month, and to then have a functional unit that does not account for this might give a bad end result. If the analyzed product or service is for instance jousting, that tend to be used continuously, this is not an issue (European Commission et al., 2010). Qualitative aspects of functional unit could for instance be that user's perception of a product or service is specified. An example of this can be two cars, that both provides the same basic functionality (transportation), but where users might perceive a specific brand as preferable to another (European Commission et al., 2010).

When working with a non-technical function in a LCA, the circumstances are somewhat different, but it is still fully doable to define the functional unit as for instance "The duration of filling one's (leisure) time with entertainment" according to European Commision et al. (2010, p. 67). In such case, the technical specifications of for instance a book and a video game console differ a lot, but they both provide entertainment. It is important though to be clear with the different attributes of compared activities in such cases.

2.4.4 System boundaries

In reality, all systems are in some way connected. However, it would make it impossible to perform a system analysis if all systems where to be taken into account, so there needs to be cut-off criteria. Steel for instance, requires coal to be made, and coal extraction requires equipment of steel, which creates a possibly infinite loop. If emissions are calculated upstream, it is however likely that the values will stabilize relatively quickly, which makes more iterations redundant since the will not affect the end result too much. A cut-off criteria could then be to stop the analysis when values do not spread outside a defined level of inaccuracy (European Commission et al., 2010).

It is also possible to qualitatively define the system boundaries, departing from what process that is in the scope of the study and what the purpose is. If the purpose is to compare two different production methods of a single product and it is likely that only the production phase will differ, but use, transportation and recycling is the same regardless of production method, those phases can be excluded from the system boundaries (European Commission et al., 2010).

2.5 Life Cycle Inventory

The main part of an LCA is generally the inventory work, regarding both duration and resources used, according to (European Commission et al., 2010). The purpose with the LCI is to identify processes within system boundaries. It is not necessary to conduct a full LCA and sometimes only the LCI is done, which is the case in this thesis. The LCI is then the final step of the life cycle assessment (European Commission et al., 2010).

2.5.1 Identifying processes

To identify processes in the system, the functional unit or the reference flow is the starting point (European Commission et al., 2010). By following all flows from when they enter the specified system to where they exit, the different processes in the system can be identified. It is important to document where in the system each process is and which processes that are connected to other systems, outside the system boundaries. Also, each identified process needs a clear description of its function (European Commission et al., 2010).

2.5.2 Data collection

Data collection is an important part of system analysis. Knowledge about processes and their relational links are needed to make a representation of the system, and data about flows and emissions are needed to perform the actual analysis. In this study, this type of knowledge has been obtained in a few different ways. Interviews have been conducted to gain knowledge from residents and other persons with an insight in conditions in the studied cohouse. This material was used to understand the organization and the different processes that take place in the cohouse, which was used to design the system. Interviews were also used to get information about electricity use and some other things such as expenditures on food.

When doing interviews aimed at obtaining knowledge about facts, (such as information about how much electricity that is used in someone's home), there is always a risk that the interviewee's subjective opinion on the matter will shine through and affects the result (Kvale & Brinkmann, 2009). To avoid this, it is important to ask questions in a manner that makes it easy to distinguish between the interviewees own understanding about things and more objective facts (Kvale & Brinkmann, 2009). This could for instance be by asking about the exact number of kilowatt-hours of electricity used per year.

Other material used in the study is printed material from the cohouse association, from the landlord and from the waste management contractor. This material was used to complement data from interviews, and to put the pieces of flows and processes in the system together. Printed material that was gained from the cohouse association was statistics about water and energy use, order lists for food from one year back and budgets from two years. From some residents, electricity bills were collected to complement interview material. From the landlord, statistics about energy use and costs for waste management was obtained and the waste management contractor contributed with statistics about volumes of waste that was used in the study.

To calculate the climate footprint from some type of consumption, it is also necessary with data about emissions from production of this particular consumption. In this study, this data have been collected by reading reports from other life cycle analyses. There are LCA's done for a lot of things, and this data is often very useful. It is however important to be aware of what is accounted for in these types of LCA's, so that the same things are counted when two LCA's are compared or so that the same type of emissions are not accounted for twice (European Commission et al., 2010).

2.5.3 Multifunctionality

If it is not possible to collect data for single processes, which often is the case, this needs to be solved. European Commission et al. (2010) presents three different approaches to this; Subdivision, system expansion and allocation, which are preferred in the order they are mentioned (European Commission et al., 2010).

Subdivision of multifunctional processes aims at dividing multifunctional processes into smaller monofunctional processes, for which data can be obtained separately. By doing so, separate processes can be studied and data still has good accuracy, and there is no need for further system expansion or allocation.

System expansion, sometimes called substitution, works by expanding the system where a multifunctional process is located. In that way, other processes further up or down the supply chain is included in the LCI. For instance, if a byproduct is produced in a process, system expansion accounts for this by expanding the system so that an alternative production process with the main purpose of producing the byproduct is included in the system. It is then possible to substitute the alternative cost (in terms of emissions etc.) for production of the byproduct from the multifunctional process. Sometimes this leads to negative inventory flows in the LCI, which might appear strange but is explained by the fact that alternative production of a byproduct might be less efficient than coproduction of the byproduct and the main product (European Commission et al., 2010).

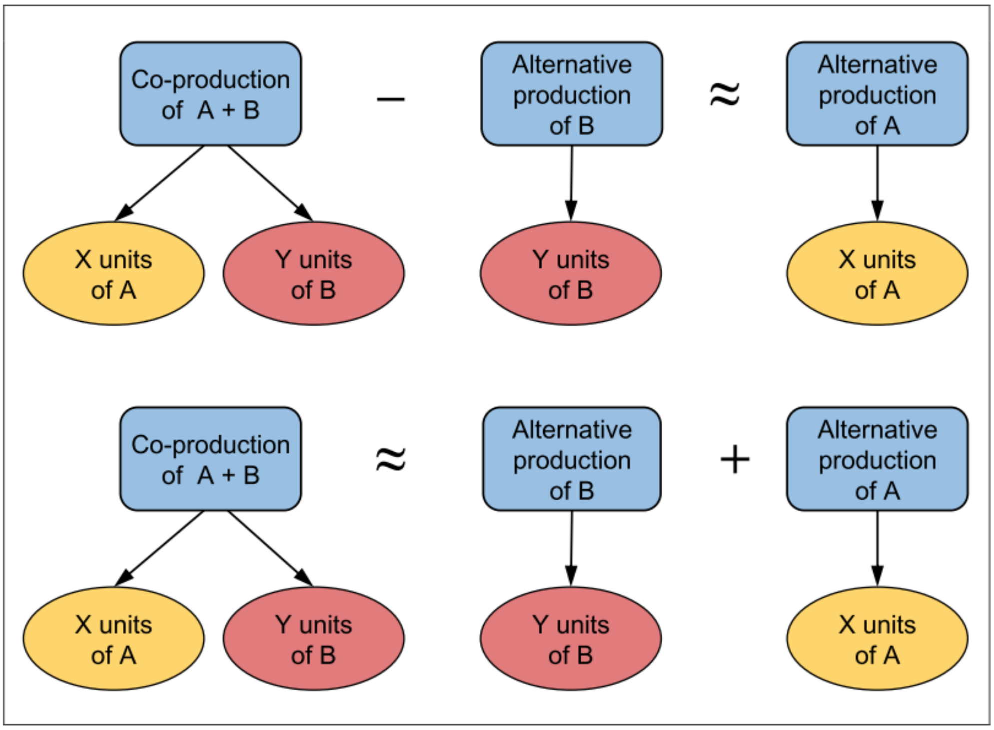


FIGURE 1 SOLVING MULTIFUNCTIONALITY BY SUBSTITUTION/SYSTEM EXPANSION *(EUROPEAN COMMISSION ET AL., 2010, P. 79)*

If it is not possible to divide a process in any other way, allocation can be used. This works by dividing flows weighted according to some criterion, for instance market price, mass or similar. For instance, it can be done when two products are produced in the same process, and the total amount of products is known. With knowledge about how much each product is sold for and total income, it is possible to estimate how much of each product that is produced. It is also possible to do these kinds of calculations "backwards", and estimate the complete production of two products if the amount of one product is known as well as the price for both (see Figure 1).

2.6 Data quality assessment

The quality of the life cycle analysis is dependent on the data used, which makes it important to be aware of the quality of the data. In this study, data quality assessment have been done based on a model proposed by Weidema & Wesnaes (1996). This model is based on three to five criteria. For each criterion, a scale from one to three has been used to grade the data, where one represents the best value. For simplicity, only the first three criteria presented by Weidema & Wesnaes (1996) have been used in this study. The first one is *reliability* which is concerned with the source of the data. The most reliable sources provide data that are verified such as from peer reviewed articles or from multiple sources or provide data directly from measurements. Less reliable sources of data are partly or completely based on estimates by either experts or non-experts (Weidema & Wesnaes, 1996). The second criterion is *temporal correlation.* This criterion assesses the age of the data, and data from the last three years prior to the study gets the best grade. Data three to six years older than the study gets a lower grade and data older than six years gets the lowest. The third criteria is *geographical correlation*, which grades the data based on where it is geographically applicable

(Weidema & Wesnaes, 1996). Data from the specific area studied gets the highest grade and data from a larger area where the studied area is included gets a lower grade. The lowest grade is assigned to data with unknown geographical applicability or data covering an area in which the studied object is not located (Weidema & Wesnaes, 1996). The full data quality assessment for this study is presented in the appendix in section 9.

3 Theory

In this section, concepts and theories that serve as a context to the case study and a base for analysis will be presented.

3.1 Sustainable lifestyles

Departing from the question "what is sustainable urban development actually, and what is a sustainable city?" (my translation), Wangel (2013, p. 1) discuss whether the physical urban environment alone can create a sustainable city. As examples of what is often considered sustainable urban development, she brings up Hammarby Sjöstad and Norra Djurgårdsstaden in Stockholm. Both districts are built on reclaimed industrial land in central parts of Stockholm and are located close to nature but still with good public transit. But while this is not something unique in a Swedish context, the strong green profiles of both districts are, according to Wangel (2013). Whether this profile has any substance to it depends on what is considered sustainable, she states. To exemplify, Wangel brings up some different views of sustainability, which prioritizes differently between economic, social and environmental factors. Wangel questions that the economic sustainability is treated as a goal in itself, and argues that economic sustainability is a means to benefit the social and environmental sustainability, not a goal in itself. She means that although sustainability is a socially constructed term, it cannot mean anything, because there are certain known facts about how much the environment is capable of withstanding without collapsing.

Hammarby Sjöstad and Norra Djurgårdsstaden are presented as good examples of sustainable urban development, but Wangel means that this is based on inadequate premises. A city cannot alone support itself with the supplies it needs, so it needs a hinterland. In today's globalized world, this hinterland tends to be relatively global. Yet, emissions from a city is calculated from what is emitted from within the city borders (Wangel, 2013). With that type of calculations, these types of district might appear sustainable in terms of environmental impact, but if counting all emissions of greenhouse gases generated by consumption done in the city, the values are a lot higher. In Stockholm over 400 percent higher, since so little goods are produced within the borders of the city while lots are consumed (Wangel, 2013). These different ways of calculating does not affect the sum of emissions globally, but it redistributes them from where they are emitted to where the consumption causing them are located, which is important from a justice point of view (Wangel, 2013). A sustainable level of emissions and energy use, based on known capacity of the environment would be one ton of greenhouse gases per person and year, globally, or 14MWh per person and year which for a person living in Stockholm requires a substantial decrease (Wangel, 2013).

Looking at Hammarby Sjöstad, homes requires less energy per square meter than average in Sweden, but on the other hand the average resident has more floor area per person than what is average (Wangel, 2013). This makes total energy use for housing relatively high, despite the efforts to decrease it. In the case of the Royal Seaport, a goal is that the district is supposed to be fossil fuel free in year 2030. But this goal does not include consumption of food or other things, neither international travel which are both categories with a major impact on total emissions and sustainability (Wangel, 2013). Wangel therefore means that it would be a catastrophe if everyone in the world lived like residents in Hammarby Sjöstad or the Royal Seaport, because the life that residents in these districts live cannot be said to have a sustainable level of resource use. To decrease the resource use, it is important to be aware of the social context, Wangel argues. For instance, if the norm is to shower every day, despite the fact that it is energy consuming, most people will probably do it in order to fit into the social context (Wangel, 2013).

What Wangel discuss is important, because she moves the discussion about sustainable urban development from not only being about the physical urban environment to also including lifestyle and behavior of residents. Even with well insulated buildings, a large floor area per person might counteract the efforts to increase environmental efficiency, and even if a person lives in a district that is built to be sustainable, their consumption and traveling affects the environment more than their home. One concept that is concerned with the relationship between the way we live and sustainability is that of sustainable lifestyles, that can be said to be a sort of subcategory of sustainable development.

Gilg, Barr, & Ford (2005) discuss the relation between sustainable lifestyles and consumption patterns, which is often a central part of sustainable lifestyles, although opinions differ. Gilg et al. (2005) outlines different views of sustainability and lifestyles, and they range from those who believe that technology will solve the environmental problems to those who believe more in a radical change of behavior and rather than "consuming green" proposing that *consuming less* is a more powerful way to decrease environmental impact. In order to investigate whether consumption patterns and a sustainable lifestyle relates, Gilg et al. (2005) asked 1600 households in Devon, UK questions about their everyday environmental actions and consumption patterns. Results showed that individuals who often consumed green also often where concerned about environmental problems in general and engaged more actively in environmentally friendly actions. Also, individuals who consumed green where often more oriented towards non-materialistic values, some even skeptic to continued growth (Gilg et al., 2005). Differences between green consumers and non-materialists is not so much touched upon in this article, but what Gilg et al. (2005) do conclude is that there are important links between sustainable lifestyles and consumption. To achieve sustainability, Gilg et al. (2005) argue that a holistic perspective is needed, and that sustainable consumption must be accompanied by change of lifestyles and behavior.

As Gilg et al., (2005) discuss, there are different branches of how sustainability and sustainable lifestyles are viewed. Following, two approaches will be discussed, one more focused on behavioral change and one more focused on technical innovation, although both of them agree that a holistic approach where all aspects are considered is needed. In a report published by the Swedish environmental protection agency, Sanne (2012) outlines a possible sustainable future and what must be done in order to reach it in 2030. Sanne's main thesis is that consumption itself is the underlying factor that causes the non-sustainable society. Therefore, he argues that we cannot solely rely on consumption to solve the environmental problems. Technological innovation is needed to achieve a sustainable development of society, but it cannot alone solve the problem with over-production and –consumption. Renewed patterns of work and approaches to consumption are at least as important (Sanne, 2012, p. 7).

When discussing housing, Sanne emphasizes that passive houses and other technical innovations are not enough, since the pace of renewal of the housing stock is so low. When the rate of construction in Sweden was at its highest level in the 1960s, less than 5 percent of the housing stock was renewed per year, according to Svane (2009). Today the rate of renewal is even lower and approximately one percent of the housing stock per year is replaced (Sanne, 2012, p. 101). In order to create sustainability in the housing sector until 2030, this means that something must be done with the existing stock as well. According to Sanne, people in Sweden have a lot of floor area per person and this is mainly because of two reasons. First, national regulations regarding housing standards have very generous definitions about what is a reasonable floor area per person. Secondly, the Swedish housing market has an inherent inertia, and there are seldom any considerable driving forces for empty nesters to switch to smaller homes. Consequently, it would be possible to use the existing housing stock a lot more effectively by accepting a bit smaller floor area per person, in Sanne's view (2012).

Sanne is also discussing private consumption, which is a key factor to change in order to reach sustainability. The main problem of today is the overconsumption, and in a sustainable future we must be ready to decrease consumption. Going back to the consumption levels of 1990 would be reasonable, but that does not necessarily mean a decreased standard of living, Sanne (2012) argues. Because of the increased productivity since 1990, we would be able to produce as much as we did in 1990 in shorter time, which would mean more leisure time which in itself can be seen as increased standard of living (Sanne, 2012). Moreover, Sanne means that a lot could be gained by using resources more efficient, and share more things. A lot of things are used very little, and by having better systems for sharing, selling or exchanging things, the need to consume new items would decrease. An important aspect to be able to decrease consumption is to change the mindset among people. Sanne (2012) claims that there might be a substantial social pressure to consume in order to assert oneself. But this can be changed, if the social pressure turns the other way around and social acceptance for consumption decreases, and it could as well be important to work with these mechanisms as with economic instruments or other driving forces to change consumption patterns (Sanne, 2012).

A bit more technology focused, although still with a behavioral concern, was a project called "One Tonne Life". The project was initiated by Volvo, Vattenfall and A-hus, and the idea was to explore whether it was possible to decrease carbon dioxide emissions to one ton per person and year (One Tonne Life, 2011). In the project, a test-family got access to more or less all the best energy saving technology available at the time, in order to see how that could affect their overall environmental footprint. But they also changed the way they ate and traveled, both during every day commuting and during longer vacational trips (One Tonne Life, 2011).

The family consisted of four persons including two teenagers and two parents in their fifties. Although the report from the project does not mention income levels, both parents are presented as having seemingly well paid jobs. A central part of the project was that the family moved into a new built house constructed as an energy-plus-house, which means that it has solar panels that produce electricity, sometimes even a net surplus that is sold. The low energy consumption from the house was also reached by thick insulation and energy efficient appliances (One Tonne Life, 2011).

For commuting, the family switched from two conventional cars to one electric car. Also, the family started to commute with public transport more often. Instead of the family's yearly skiing trip to the Alps, which meant going there flying, they went to the Swedish mountains by train. Regarding food, the family was informed about emissions from different foodstuff, and tried to eat more efficient. The main changes where that they ate more seasonal food, made use of leftovers and tried to consume less meat (One Tonne Life, 2011).

In the end, the project did not reach the goal of one ton of carbon dioxide emissions per person and year, but the family managed to lower their emissions substantially. For housing and food, while still living in a way they considered long-term acceptable they reached below 2 tons of greenhouse gases per person and year. Including transportation and other consumption, emissions were about 3 tons per person and year, which was less than half of their emissions before the project. The biggest percentual change was for transports, where the family's emissions decreased with over 90 percent. Energy for heating decreased with over 50 percent, compared to the family's levels before the project. The family also tried to consume less other things in general, which reduced carbon dioxide emissions by half from this type of consumption. The sum of all emissions savings added up to 62 percent lower emissions compared to what the family initially emitted. This level was on a so called "comfort-level", where the family felt like they could continue their current lifestyle in the future as well. When they tried their hardest to decrease emissions, they lowered them with 79 percent. This however required a lifestyle that the family did not feel comfortable with and could maintaining for an extended time period (One Tonne Life, 2011).

In terms of absolute savings, transportation was the biggest factor. By using an electric car, but also by actually driving less, the family cut emissions with about one ton of carbon dioxide emissions, and by not flying, they cut another ton, per person and year. Emissions from the family's home sank with about a half a ton per person and year, which is actually a smaller saving than what the families changed eating habits resulted in, which was about 600 kilos per person and year, on a long-term acceptable level, which was possible to stretch twice as low with an effort that the family did not consider acceptable in the long run. That level required a more or less vegan diet, which the family did not want to maintain after a few weeks of trying it. Decreased levels of other consumption also saved about one ton of carbon dioxide emissions per person and year (One Tonne Life, 2011).

What this experiment shows is that there are a lot of potential to decrease carbon dioxide emissions, in the home and elsewhere. Since this thesis is concerned with the home, it is interesting to see that there was no single factor that mattered the most, but there seems to be rather similar sized saving-potentials everywhere, which shows the need for a holistic perspective on housing and environmental efficiency. Also, the "One Tonne Life"-project showed that behavior impacts a person's environmental impact a lot, and that the best technology available at this time cannot alone solve the environmental problems. This highlights the importance of giving awareness to the link between behavior and environmental impact.

In relation to what Sanne (2012) discuss, the conclusions from the "One Tonne Life"-project are in the end not so different. Sanne argues that humanity needs to consume less, since consumption requires resources and causes emissions of greenhouse gases. Sanne also means that consumption and labor is interlinked, and in order to decrease consumption, the number of worked hours needs to decrease. This can be seen as a way to change people's lifestyles on an institutional level, consisting of a redistribution of time and resources. Less work means more leisure and less consumption (Sanne, 2012). One Tonne Life (2011) does not discuss any particular driving forces that should make people consume less, but the project clearly shows that decreased consumption and different consumption patterns clearly can result in decreased emissions. Therefore, it is somewhat surprising to see that the living area in the building in the "One Tonne Life" project was 155 square meters, which is 38 square meters per person for a family of four. That is actually one square meter more than the average living area per person, for couples with 2 children in detached houses, which is 37 square meters per person (SCB, 2008). Sanne (2012) argues that it might be a good idea to consume less housing in order to decrease resource consumption, which usually means living a bit smaller, but in the "One Tonne Life" project, living area is not treated as a variable that can be changed and affect the overall carbon footprint.

As Sanne discuss, the pace of renewal of the housing stock is very low, which means that a holistic approach to sustainable urban development needs to include the existing stock and not only new built buildings and districts. The question is how this can be done; what aspects are important and what is possible to change without too much effort? Considering the slow pace of renewal of the housing stock, it seems quicker, easier and less resource intensive to use the existing housing stock more efficient and decrease the floor area per person. Regarding lifestyle, it appears as if Sanne (2012) is more change oriented, since he clearly states that people need to rethink their material standard and learn to appreciate other less material things such as more leisure. A changed mindset might also be needed to accept less floor area. One Tonne Life (2011) does not go as far, and rather than proposing a radical shift of lifestyle, the project, in a nutshell, tried to allow the test family to continue their current lifestyle but tried to minimize the environmental impact from it.

3.2 Cohousing

3.2.1 History of Swedish cohousing

The idea of cohousing can be said to date back to the 16th century, and to Thomas Moore's Utopia. However, cohousing mostly remained an idea until the early 1900s (Vestbro, 2010b). With the far-reaching industrial revolution followed ideas about how to bring the industrial development into people's homes. In 1907, a building called Hemgården was finished in Stockholm. It was innovative building in many ways, and the 60 apartments lacked private kitchens. Instead, residents got food from a central kitchen with employed staff delivered into their apartments with food elevators. The developer however went bankrupt after a few years and the building were rebuilt to a more regular one (Vestbro, 2010b).

The cohousing idea went to rest for a few years in Sweden, but during the 1930s, it was brought up again together with the emergence of modernistic and functionalistic ideas. The architectural manifesto "acceptera" from 1931 proposed that future housing could be collectively organized (Vestbro, 2010b). In the book "Kris I befolkningsfrågan" that came out a few years later, Gunnar and Alva Myrdal discussed the low nativity in Sweden at the time. They were worried that the present development would lead to a situation where the amount of elderly would be a lot bigger than the labor force, which would make it hard to provide good welfare for everyone. As a solution, they proposed a number of actions that would make life easier to for dual earner households with children (Myrdal, 1935; Vestbro, 2010b). One field they wanted to improve was the housing situation in general, which resulted for instance in housing especially for families with children, but Alva Myrdal and architect Sven Markelius also developed the idea of multifamily houses where meals were to be cooked centrally in the house by employed staff and delivered with elevators directly into the apartments, or in a restaurant (Vestbro, 2010b). In 1935, a cohouse was built in Stockholm at John Ericssongatan 6 according to these ideas. In some ways, the concept was similar to the cohouse Hemgården from the beginning of the century, but while that house mainly was aimed at the bourgeoisie, Myrdal and Markelius wanted cohousing to be a way to decrease the domestic work for everyone, and especially women (Vestbro, 2010b). The building had child care with employed staff around the clock in order to make it possible even for single mothers to conduct wage labor (Myrdal, 1935; Näsström, 1935).

Social life in the building was not a main target (Vestbro, 2010b). Since food was served in the apartment, and laundry was sent down a chute, social contact was not necessary between neighbors. As it turned out, the idea was mainly supported by intellectuals and women and not so much adopted by the broader labor organizations as Myrdal and Markelius would have hoped for. Apartments were mainly small, and rather than by families, the building came to be occupied by radical intellectuals (Vestbro, 2010b).

Proponents of cohousing at the time hoped for support from labor movements such as HSB and the social democratic party, to spread the concept to a broader audience, but this did not happen. However, private contractor Olle Engkvist started to build cohouses. One of his cohouses was located in Marieberg. Apartments in the building were small, but still equipped with some kitchen facilities (Vestbro, 2010b). The building also had a shared central dining hall with employed staff. An important feature to make people use the dining hall was food coupons that were compulsory to purchase for tenants. Thus, dining together with other residents became an integrated part of the social life in the building. Because of the small apartments, the house became occupied by a large share of single mothers, who appreciated the relief of domestic work that the house contributed to. Olle Engkvist continued to develop cohouses, but the model with employed staff gradually turned obsolete. With increased salaries, it became expensive. Technical development of things that made domestic labor easier, such as freezers, prefab foods and laundry machines also made the need for employed staff smaller (Vestbro, 2010b).

One of the largest cohouses that Olle Engkvist built was the Hässelby family hotel, which had over 300 apartments, and shared facilities such as a dining hall with employed kitchen staff. In the 1970s, the landlord decided to close the restaurant. To the residents, the restaurant was an important part of social life as well as making everyday life easier, and they wanted to keep it (Sangregorio, 2010). The residents themselves therefore started to use the communal kitchen and cooked for each other. This was the start of a sort of second wave of cohousing which today's cohousing movement originates in (Sangregorio, 2010). Among the actors interested in the transformation of the cohouse in Hässelby was the Swedish feminist group Grupp 8 that fought for gender equality in the 1970s. Similar to Myrdal in the 1930s, lack of adequate childcare was one problem they recognized that prevented mothers from working full time or made women have to choose between a career or children. For Grupp 8, the idea of cohousing was central as a step to achieve gender equality. By sharing some of the domestic work, it would put a smaller burden on women, their idea was (Sangregorio, 2010). Another important aspect of this was also to make the domestic work that was, and to some extent still is, traditionally done by women more visible, which would help make it treated as "real work". With cohousing, it was possible to achieve this in shared spaces and still keep some private space (Sangregorio, 2010).

3.3 Organization and structure in cohouses

"In the collective houses of today the pendulum between privacy and community has stopped in a delicate position of trying to combine both." (Palm Lindén, 1992, p. 3)

A common misunderstanding is that cohousing is the same thing as a commune. That is however not the case. Where people in a commune live together in a single building or apartment, people in a cohouse have their own often fully equipped apartments on top of a communal kitchen and other shared spaces. (Palm Lindén, 1992; Vestbro, 2010b). Typically, in cohouses some meals are shared but not all. It is important to distinguish cohousing from other types of housing with shared meals such as retirement homes for elderly. In most contemporary Swedish cohouses, meals are cooked by the residents themselves on a running schedule, so that they cook for their neighbors every once in a while, as opposed to cohousing with employed staff that was the common model until the 1970s (Grip & Sillén, 2007; Vestbro, 2010b).

A typical organization in cohousing developments is that dinners during weekdays are shared. For residents, it means that they cook for their neighbors a couple of times per month, depending on the size of the cohousing development. The other days, they get dinner served and do not have to cook, or to clean the dishes. Normally, it is not compulsory to have dinner, but it is compulsory to cook for the others or to do other work (Carlsson-Kanyama, 2004; Familjebostäder, 2008; Helander, 2013; Vestbro, 2012). In some cohousing developments, residents must register if they want to participate in communal meals. In other cohousing developments, they do not need to do this, which makes planning harder for those who work in the kitchen, but increases flexibility for residents (Carlsson-Kanyama, 2004).

Palm Lindén (1992) means that cooperation, common responsibility and common use of goods and facilities is central ideas in cohousing, and following, a cohouse should make this possible. This means that a cohouse should include a big shared kitchen, shared living room and other shared spaces and facilities. Although social factors are central in cohousing, the building itself is important to create an adequate space for communal activities. With good architecture, the building could help increasing contact between neighbors (Palm Lindén, 1992). There are around 50 cohousing developments in Sweden, and they range in size from 15 to 80 apartments, where 30 apartments is the average (Palm Linden 1992). Swedish cohousing developments mostly seems to be in the form of multifamily houses, but for instance in Denmark, there are also cohousing developments consisting of detached houses and shared buildings with kitchen and other facilities (Vestbro, 2010a). The Swedish National Board of Housing, Building and Planning distinguish between tenure and type of housing. It should be noted that cohousing is not a specific tenure, but a type of housing (Boverket, 2013). Cohousing developments does not have to have a specific tenure. According to the Swedish cohousing association Kollektivhus NU (2014), Swedish cohousing developments are most commonly rentals, mainly conventional rentals, but also cooperative rentals where the tenants themselves own the building collectively. About 20 percent of the cohousing developments are in the form of housing cooperatives.

Some argue that rental tenure is more suitable for cohousing, because of the increased control over who moves in. Like with regular rentals in Sweden, vacant apartments are rented to the person with the longest time in the housing queue. What differs, though, is that there might also be some kind of selection process involved, where potential residents are interviewed before moving in, or residents are chosen to create a mix of residents with different gender and age or who fits into the social context (Uppsalahem, 2011; William-Olsson, 2014). Communal activities in cohousing communities are often managed within a local cohousing association (Fletcher, 2007). The common arrangement in Swedish cohouses seems to be that there is some kind of deal between the landlord and the cohousing association to ensure control over communal facilities and space, as well as over new tenants. This means that the landlord gives some degree of power to the cohousing association to choose between potential new residents (Fletcher, 2007). The control over who moves in is sometimes mentioned as an argument for rental tenure in cohousing (Sandström & Gray, 2010; Vestbro, 2009). A common procedure is that people from the cohousing association conducts interviews with potential new neighbors to see that they know what cohousing is about, and if they seem to fit in the social context (Fletcher, 2007). With housing cooperatives, where shares in the cooperative (apartments) generally are traded on a free market, this does not automatically work. Usually, the prospective buyer who places the highest bid gets to buy the apartment.

3.4 Cohousing outside Sweden

This thesis is mainly concerned with cohousing in a Swedish context, but it is important to point out that cohousing as a concept is by no means isolated to Sweden. There are several cohousing communities around the world, for instance in Germany, Denmark, the United States and in Japan (Vestbro, 2010b). While the basic idea of sharing your living with your neighbors is the same, there are also some differences. In Sweden, most cohousing developments are in the form of multifamily houses, but in both Denmark and the United States, there are also examples of cohousing developments with detached houses. In these cohousing communities, households have their own house, but there is also a sort of community building where communal meals take place (Vestbro, 2010b). In Germany, so called baugemainschaften, construction communities, are relatively common. A baugemeinschaft is typically a concept that means that a group of people goes together to build a multifamily house which they will later live in. By taking the initiative to build their home themselves, they can be more influential over the final result. This type of living shares similarities with cohousing, in that the future residents are more deeply involved in the design and construction of their home than what is usual for conventional housing, and that they later will own it collectively. A baugemeinschaft can be built in the form of a cohouse, but it is not necessarily built so. The outcome might vary, and it is not necessary to have a lot of shared space or communal activities, but since the work with building and maintaining the baugemeinschaft is shared between the neighbors, a strong sense of community is needed and likely reinforced among residents (Vestbro, 2010b).

3.5 Examples of Swedish cohousing

To give an idea of how cohousing can be arranged, some examples of Swedish cohouses are presented in this section.

3.5.1 Cigarrlådan, Hökarängen

The cohouse Cigarrlådan is located in Hökarängen, a suburb a 20 minute subway ride south of central Stockholm. The project was initiated by the group "Hökarängens kollektivhusgrupp" (Hökarängens cohousing group) in 1985. The group wanted to convert an existing building into a cohouse rather than building a new house, in order to keep costs down. Cigarrlådan is therefore located in a typical 1950s multifamily house in three floors, which was not initially intended for cohousing. Because of this, the communal spaces are smaller than in other cohouses (Kollektivhusföreningen Cigarrlådan, n.d.). Cigarrlådan has 22 apartments with rental tenure: 6 one room apartments, 11 two room apartments, 3 four room apartments and 2 six room apartments. Among the residents, there are many families with children[1].

[1] Person a, resident in the cohouse Cigarrlådan for five years, personal communication 24/5-2014

The main communal activity in Cigarrlådan is the shared dinners, which are had on weekdays. Residents are divided in different cooking teams, and usually a resident cook about every sixth week. Basic foodstuffs such as pasta or grains are ordered to the cohouse. The rest of the food is bought and paid for by those who cook. The common denominator for the meals is that they need to be vegan, or at least that a vegan alternative is served. Recently, there have been many parents with new born children, and they do not have to cook for the others during the first months of their parenthood. The residents in Cigarrlådan clean communal spaces themselves, and each resident have their own area of responsibility[2].

There is a garden outside the cohouse, and it is a good platform for discussing and practicing sustainability, also with the children in the community. Generally, residents are environmentally aware, and since adults and children spend time together, the awareness tends to spread. Other communal activities are parties, playing games or just hang out together. It is also common among residents to help each other with babysitting, or to exchange services such as doing a webpage for a neighbor and get some other service back. There is no formal sharing system for things in the cohouse, but people often lend each other private belongings[3].

Once a month, there is a meeting in the cohouse where everyday matters such as what is to be bought communally to the cohouse are discussed, as well as questions about the ideological foundation of the cohouse. During the meetings, conflicts or issues regarding communal activities are discussed. If a resident do not want to discuss an issue in person, they can let someone else speak for them. Conflicts in the cohouse generally revolves about tasks such as conflicting levels of ambition with cleaning and similar, but sometimes also around personal matters[4].

3.5.2 Kollektivhuset Södra station, Södermalm

The cohouse “Kollektivhuset Södra Station” is located in the district of Södermalm in central Stockholm. I was built in 1987 and it has 63 apartments (Kollektivhuset Södra Station, n.d.).

The cohouse has around 180 residents. Communal cooking is a central activity in the cohouse and communal dinner is served Monday-Thursday. All residents must work 2 hours per month with communal meals in some way. It can be in the form of cooking, doing the dishes or do grocery shopping. The communal meals had more participants a few years ago, but participation varies over the years. There is a bit of division in groups, so that there are those who usually eat communal dinners, and those who do not, rather than an equal level of participation in the whole community. Families with small kids tend to appreciate the shared meals because of the decreased domestic labor[5].

Other activities sometimes pop up, if a group of residents wants to do something. Examples of such activities are music nights or dance groups. Single mothers sometimes meet and drink coffee or help each other with babysitting. In general, most households in the cohouse are families with children, or were when they moved in but are now empty-nesters[6].

---

[2] Ibid.
[3] Ibid.
[4] Person a, resident in the cohouse Cigarrlådan for five years, personal communication 24/5-2014
[5] Person b, resident in the cohouse Kollektivhuset Södra Station for 19 years, personal communication 15/5-2014
[6] Ibid.

Shared spaces are a kitchen and dining room, a workshop, a music room, a painting room, an office, a guest apartment and a laundry room. One source of conflict was the tenure conversion that happened a few years ago, from rental tenure to cooperative housing[7].

3.5.3 Blenda, Uppsala

The cohouse Blenda in Uppsala consists of 24 apartments, ranging in size from one to five rooms. Blenda was founded in the 1980s, and is arranged according to the self-work model. Anyone are allowed to move in, and as of 2013, there were for instance students, newly graduated students and families with kids living in the house, according to Helander (2013). The cohouse is owned by the municipal housing company Uppsalahem, and apartments are mediated by the regular housing queue. However, current residents have the right to conduct interviews with potential residents and deny them an apartment in the cohouse (Uppsalahem, 2011).

The communal spaces in the cohouse include a playroom for kids, a sauna, a gym, a workshop and three guestrooms. There is also a communal kitchen and dining room. Shared dinners are cooked on weekdays by residents. Cooking service is voluntarily, but a resident who do not cook need to do something else instead, like cleaning communal space. There are also different workgroups in the community, with different areas of responsibility. For example, there are workgroups for culture, housekeeping and kitchen management (Helander, 2013).

Residents who take part in the shared dinner pay 20 SEK and if there are any leftovers, food packages can be bought for 25 SEK. Those who are cooking during a week are buying the groceries, and they need to cook 30 meals on five weekdays for 2000 SEK. Anything on top of the budget needs to be covered by those who cook. Considering the constrained budget, buying ecological foodstuff without having to pay extra money is often not possible (Helander 2013).

3.6 Cohousing and sustainability

Social sustainability historically has been, and maybe still is, the main point of cohousing. As discussed earlier, there are however reasons to believe that cohousing also could be a good way to increase environmental sustainability.

In a paper with the somewhat self-explanatory title "Saving by sharing", Vestbro (2012) outlines how cohousing provides a good platform for sharing resources. By sharing things and services in a cohouse, Vestbro argues that the overall consumption of resources per person can be lowered. In his words, cohousing "can be assumed to facilitate behavior change on the grounds that community cooperation is already established and that consumerist lifestyles are often not highly valued" (Vestbro, 2012, p. 2). What can be read from this is that resources are saved by sharing, but also that there are less visible mechanisms of social control that makes it less appealing for residents to consume unnecessary things. Living in a cohouse in Stockholm himself, Vestbro gives a number of examples of things the residents share.

One is the sharing of space. By having communal spaces that are larger than in regular housing, residents can accept living a bit more compact. Still, the total space per person, private and communal, can be smaller than the average. Another is sharing of material things. This could be tools, garden equipment or subscriptions of journals, to name a few (Vestbro, 2012). Vestbro means

[7] Ibid.

that it is easier to set up a so called LETS, a local exchange and trading system in a cohousing community since residents know each other well and are used to cooperate and share things. If this is the case, it is interesting to know how much that can be saved from sharing of products, space and other resources.

In the article "...But most buildings are already there: Basic starting points for environmental management in the housing sector", Svane (2009) takes an interesting approach to housing and environmental impact, when he describes a building as a "flow pump". As Svane describes it, a building has several flows of resources pumping through it while it is in use; "Each year, a person in average carries about a ton of food and other daily goods over the threshold of his/her flat. Part of it eventually leaves the flat as household waste. The rest is due time delivered to the sewage system." (Svane, 2009, p. 152). Moreover, Svane states that: "Its [the buildings] lack of environmental sustainability is in the first hand in the flows of resources and waste, energy and matter that it pumps for its users in order to deliver to them the services they expect. (Svane, 2009, p. 153). Although he does not specifically discuss cohousing, but any type of housing, the reasoning is an interesting starting point when discussing sustainable housing. The question this text raises is the different ways that the volume of the flows pumped through the building can be affected.

In one of few detailed studies of environmental efficiency and cohousing, this issue was approached by Annika Carlsson-Kanyama (2004). In the study, Carlsson-Kanyama investigates whether it is more efficient with shared meals in cohousing developments compared to regular individual meals, in terms of energy use and food waste. The first theory is that there is a potential to save energy by economies of scale when cooking and storing food, since it is done collectively. Because of that, the energy use that is required to cook one portion might be lower than what it is for regular small scale cooking. The second theory is that the amount of waste generated from communal large scale cooking might be lower (per person) than from regular cooking, since knowledge and skill about food preparation easily can be shared. It is assumed that with more skill, the amount of waste will be smaller (Carlsson-Kanyama, 2004). To test if these theses holds true, Carlsson-Kanyama visited two cohouses and studied what they cooked, how they cooked it and general organization of meals and cooking. The first cohouse was described as slightly softer organized, whereas the second cohouse was presented as more strictly organized. The first cohouse did not require residents to sign up for dinner, and the communal kitchen was equipped with standard kitchenware for private kitchens. The number of residents was also smaller than in the other cohouse, and children were allowed. The second cohouse was larger, and limited to residents without children over 40 years old. The kitchen was equipped with large scale appliances, like those at restaurants, and residents needed to register for dinner the same morning (Carlsson-Kanyama, 2004).

Three meals in each cohouse were studied, and the environmental efficiency of the cooking procedure was estimated. Energy use was measured by cooking the same amount of food with the same methods as in each cohouse in a kitchen lab equipped with instruments able to measure the use of electricity. On top of that, energy use for refrigerators and freezers was calculated. Food waste was estimated by measuring the weight of it, and the total amount of foodstuff to get a percentage of the share of the raw materials that became waste.

The study showed that energy use for storage of food was slightly higher in a cohouse, assuming that each resident have their own fridge plus a share of the communal fridges. For cooking, the opposite was evident, and when cooking 25 portions of potatoes, rice or spaghetti, the energy use per portion was about a quarter of what it takes when cooking one portion at a time. The amount of food waste during preparation did not differ a lot between the two cohouses in the study and was generally lower than in industrial food preparations. It is unclear how the amount of waste relates to regular households amounts, since statistics are old, but there is according to Carlsson-Kanyama no reason to believe that it would differ a lot. The amount of leftover did however differ between the cohouses and were significantly lower in the cohouse where registration before dinner was compulsory. Both cohouses have systems to take care of leftovers so that they can be consumed as lunch the day after, for example (Carlsson-Kanyama, 2004).

Based on Carlsson-Kanyama's conclusions, it can be assumed that energy use per person is lower in a cohouse when it comes to cooking, but what she does not investigate is the total energy use in a cohouse. There might be other activities that affect the overall use. Communal cooking could for instance possibly decrease the need for a complete private kitchen with full size fridge and freezer, which might compensate for the extra energy communal fridge and freezer requires. Therefore, it is interesting to get a picture of the overall energy use as well.

There are also other dimensions of sustainability in cohousing. The social sustainability is often put forward as a strongpoint of cohousing. Sangregorio (2010) means that cohousing is relieving for families and others who combine paid work with taking care of children. Today, the government tries to tackle the problem with keeping up with both paid and domestic labor and increase gender equality by using tax reliefs to make it cheaper to employ staff to clean and maintain people's homes, according to Sangregorio (2010). In her view, cohousing is a better way to achieve the same thing.

The shared meals are another aspect that might contribute to environmental sustainability, but also social. During a workshop about shared meals at a cohousing conference in Stockholm in 2010, participants emphasized the importance of the shared meals in cohousing communities as a form of social bond, around which a lot of the communal activities in the cohousing development are centered. In the notes from the workshop, it is stated that "There was a consensus that the shared meal is pivotal to community; it is about more than a meal; it plays a key social (and political and ethical) function." (Jarvis & Fransson, 2010, p. 181).

Vestbro (2012) is on the same track, but also emphasizes the environmental dimension: "Although the main reason for this [shared meals] is to provide for a sense of community and to save time for residents, it is generally assumed that common meals also save resources."(Vestbro, 2012, p. 10). At a workshop held at a cohousing conference in Stockholm in 2010, with participants from Sweden as well as from abroad, the food culture of today was discussed: "It was also noted that common meals foster trust and consensus – in opposition to arguably damaging, individualistic Western fast food dining practices." (Jarvis & Fransson, 2010, p. 178).

4 Case study: system analysis of Färdknäppen

The case study was done in the cohouse Färdknäppen and in the following section, the cohouse is presented in general and the various activities that takes place in it are examined. This background is the base for the construction of the system analysis model which is also discussed in this section.

4.1 Färdknäppen

The Färdknäppen cohouse is located in the Stockholm inner city district of Södermalm. The cohouse was built in 1993 as a part of the urban development project on and around the site for the old rail yard of Södra station (William-Olsson, 1994). The building is a 7 story multifamily house with 43 apartments, in sizes ranging from one room and 37 square meters to three rooms and 75 square meters, all with rental tenure. The bottom floor almost entirely constitutes of shared space. On top of the house, there is a roof terrace and a common room. There is also a small garden behind the building (William-Olsson, 2014). In total, the building is 2661 square meters, of which 345 square meters are shared space, not including staircases and similar spaces (Kärnekull & Blomberg, 2013).

The discussions about the cohouse started in 1986, when a group of people interested in cohousing formed a cohousing association. Their aim was to create a cohouse were residents could grow old together, and not be left alone when their kids moved out. The group together discussed how their ideal cohousing community would look, and looked for a suitable building. In discussions with the communal housing company Familjebostäder they finally came up with the solution to build a completely new cohouse, as opposed to their initial plans to convert an old building into a cohouse (William-Olsson, 1994).

The planning process involved a lot of discussions and controversies and some people left the cohousing association. There were also discussions with the architect and the developer during the planning of the cohouse. A source of conflict was the difficulties that the cohouse association had with convincing the developer and the architect about their special needs and requests, which differed from the standards in conventional housing. For instance, they wanted smaller kitchens than what were allowed by housing norms at the time (William-Olsson, 1994).

Today, there is a high demand for apartments in Färdknäppen. If someone wants to move in, they first need to become a member in the cohousing association. During the waiting time for a free apartment, they can participate in the communal activities in the house, such as participate in the communal cooking. When a vacancy needs to be filled, the contract is given to someone in the cohousing association without an apartment, depending on who is considered suitable for the overall social structure in the house. Criteria that are looked upon are for instance age and gender, since the cohouse association is concerned about having an equal distribution of residents based on these factors (Fletcher, 2007).

4.2 Organization and characteristics of Färdknäppen

To understand the organization and structure in Färdknäppen, I visited the cohouse three times during the spring of 2014. During my first visit on Monday 31st of March 2014, I participated in a communal dinner and was shown around in the house. During my second visit, on Tuesday 8th of April 2014, my main target was to gather specific data, which was done by doing short interviews with two residents and looking at order lists for food. On the third visit I gathered data about energy use and discussed it with two residents.

The criteria to move into Färdknäppen are that a resident is older than 40 years, and do not have any kids living at home. Today, there are about 80 percent women and 20 percent men in the cohouse, and many residents have been living in the cohouse since it was built. Since many of the original residents were around 40 or 50 when they moved in about the 20 years ago, the average age nowadays is somewhere around 70. However, to be able to grow old in the house was a goal when developing the idea, and it works well[8].

As mentioned, almost the entire bottom floor in the building is shared space. The kitchen is 54 square meters, and it is equipped with industrial grade kitchen appliances (see Figure 2). Next to it, the dining room is located, which is 56 square meters (Grip, 2007). There have been discussions about refurbishing the dining room and its furniture. Tables are a bit old and worn, but since they still do the job, residents decided to keep them[9]. There is also a common room with a library and a big screen TV. A library group is responsible for getting new books to the library, and they also take care of newspaper and magazine subscriptions. During 2013, the library budget was 3000 SEK (Kollektivhusföreningen Färdknäppen, 2014).

FIGURE 2 THE COMMUNAL KITCHEN IN FÄRDKNÄPPEN (PHOTOGRAPHY BY THE AUTHOR, 2014-03-31)

There is also a workshop with tools such as a pedestal drill. The workshop doubles as a room for garden equipment. There are several shared computers and a copy machine placed in a communal office. Many residents have their own computer too, but it is not common to own a copy machine individually in the cohouse[10]. It is common with "unofficial" sharing of things in the cohouse, on top of the organized sharing. The resident's experience of sharing things in general creates a good climate for sharing also their private belongings[11].

In general, dinners seem central in the community and residents have the possibility to eat dinner together from Monday to Friday. Cooking is done by the residents themselves and they are divided into six cooking teams that are responsible for dinners every sixth week. During a cooking team's

[8] Person c, resident in Färdknäppen, personal communication 31/3-2014
[9] Ibid
[10] Person d, resident in Färdknäppen, personal communication 8/4-2014
[11] Person e, resident in Färdknäppen and member of BiG, personal communication 31/3-2014

week, the team is responsible for planning the menu, buying missing groceries, cook and clean the dishes. Residents who want to eat need to buy food coupons, and the cost for a dinner was during spring 2014 24 SEK, except on Fridays when dessert is included and the price is 40 SEK. If there is excess food from the dinners, it is put in boxes and sold for 16 SEK. In order to have dinner, residents also need to register at the latest 9 o'clock in the morning the same day, except on for Friday dinners for which registration needs to be done on Thursdays. Guests can be invited as long as they are registered and paid for[12].

During week 14, 2014, there were 64 names written on the dinner-registration list (see Figure 3). Registration is done by marking ones name with a cross, and on the Monday evening I visited, there were 35 persons registered for dinner, which is average, according to William-Olsson (2007). There are only 53 persons actually living in Färdknäppen, so the other 11 persons were either guests or so called "guest workers". These persons are called "guest workers" by the residents in Färdknäppen since they participate in dinners and are part of a cooking team in the same way as ordinary residents, without living in the cohouse[13].

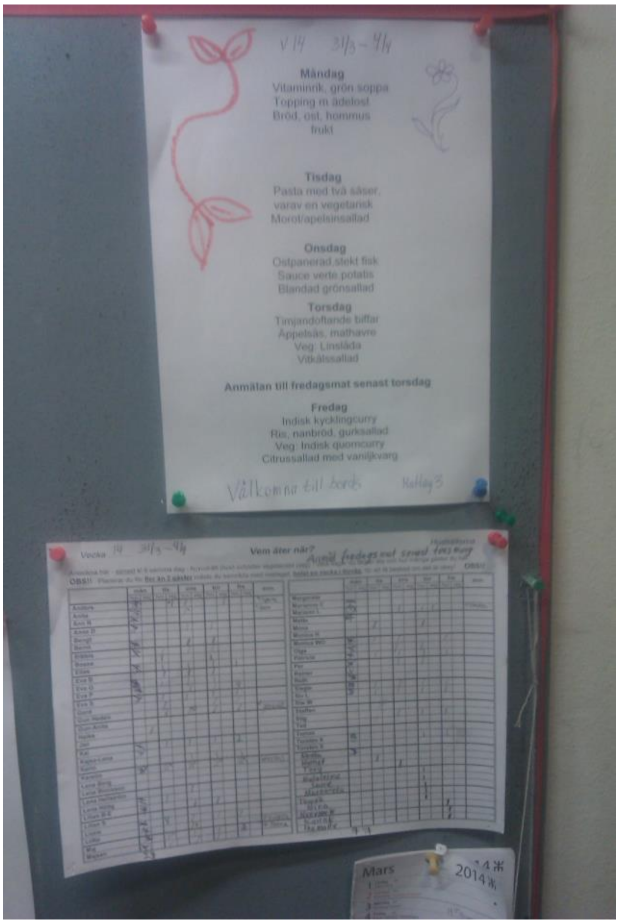


FIGURE 3 DINNER MENU OF THE WEEK AND REGISTRATION LIST (PHOTOGRAPHY BY THE AUTHOR, 2014-03-31)

The residents themselves take of care of cleaning of communal spaces and garden maintenance. Since this is normally accounted for by the landlord Familjebostäder, the cohousing association is paid 90000 SEK in compensation. 25000 SEK of this money is used to subsidize the otherwise self-financing dinners and keep the prices down, since they are considered to be such an important part of the community and the cohousing association wants everyone to afford participating in the communal dinners. Because of the same reason, foodstuff is generally not organic, since that is considered too costly[14].

Except from the dinners, there are several other communal activities in Färdknäppen that takes place on a regular basis. On the Monday night I was visiting there were both choir-practice and an evening class going on, and both seemed popular. Other communal activities during 2013 were according the cohouse associations annual report movie nights, reading group, doing jigsaw puzzles and maintaining the garden (Kollektivhusföreningen Färdknäppen, 2014).

[12] Person c, resident in Färdknäppen, personal communication 31/3-2014
[13] Ibid.
[14] Person f, resident in Färdknäppen, personal communication 14/4-2014

Electricity for communal spaces is paid for by the cohousing association while the resident's individual electricity is paid by themselves, divided per household[15]. The cohouse has its own garbage room, with waste sorting. The room looked very well maintained each time I visited. Waste is sorted in several different fractions, such as plastic, glass, metal, organic waste and paper. There is also reuse section in the room, where residents can put functional stuff that they do not want so that it can be reused, rather than being thrown away.

4.3 Functional unit

The functional unit in this analysis is formulated as "meeting the housing needs for one person during one year". It is important to point out that "housing needs" in this context not only means the physical building, but is also meant to include domestic activities that take place in a home, such as cooking or washing, sometimes called domestic labor.

The purpose with a functional unit formulated like this is to be able to compare the use phase of housing types, in this case cohousing and regular housing, and not treat domestic activities that takes place inside the buildings as static factors beyond control of residents.

"Housing needs" also has qualitative aspect to it, since what people perceive as "satisfying their housing needs" might differ a lot. For people living in cohousing, it is reasonable to assume that cohousing satisfies their needs, since they choose to live there. For others, cohousing might not be an alternative, because of their preferences. In this way, cohousing might not always meet the housing needs for a person, but that is likely to be because of qualitative preferences and not because of quantitative reasons, such as not providing shelter or sufficient amounts of food. According to European Commission et al. (2010), a comparison is still absolutely possible as long as differences are clearly described.

4.4 System boundaries

The lifecycle of a building can comprehensively be said to consist of a building phase, a use phase and a demolition phase. A common approach to analyzing the environmental impact from a building seems to be to include all phases of the lifecycle of a building, including among other things production and transportation of materials, fuel for machines during construction, use and maintenance of the building, demolition and recycling of materials. For instance Dahlstrøm, 2011 and Melvær, 2012 used this approach to do LCAs of passive houses in Norway and included construction, use and demolition. In studies with that approach, the processes during the use phase is treated as static factors which are calculated with average data or similar, since going too much into details would require a lot of work in such cases, or not be possible with new or future buildings.

[15] Ibid.

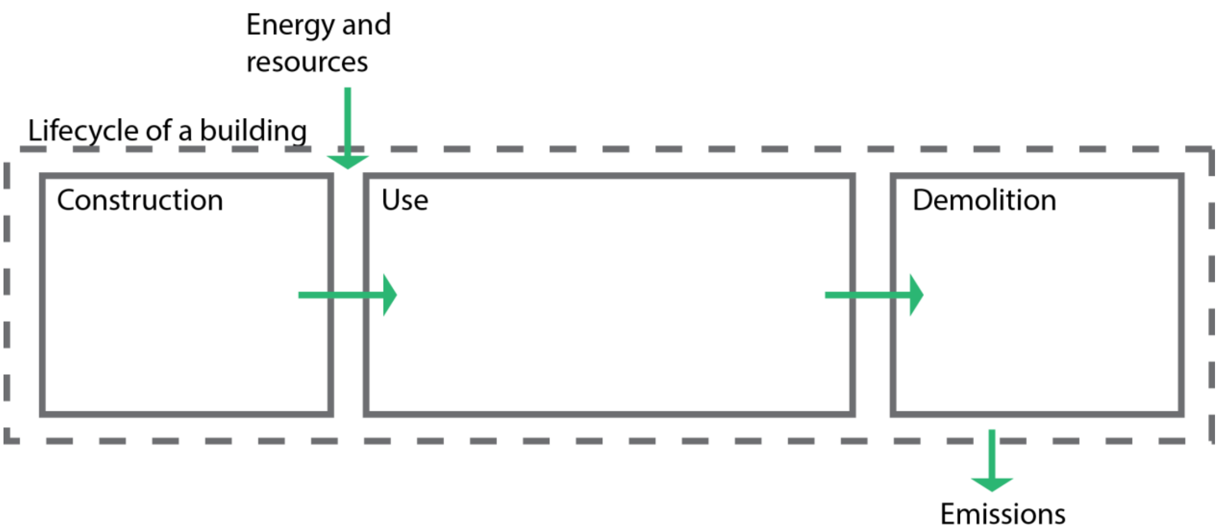


FIGURE 4 COMPREHENSIVE LIFECYCLE OF A BUILDING

In Figure 4, a comprehensive diagram of such full lifecycle of a building is shown. Here, the use phase is just one box or process in the lifecycle. There are also LCAs of the use phase only, focused on the technical systems. In studies with that approach, human behavior is again commonly not considered to be a parameter that affects the result. Instead, insulation and technical systems are the focal points of the study (Dahlstrøm, 2011 and Melvær, 2012). What a system like the one above (in Figure 4) does not capture is the human dimension. As for instance Wangel (2013) or Svane (2009) discuss, the overall environmental impact is likely to be dependent on human behavior as well, and not only on the technical systems of people's homes. Approaches treating the use phase as static might not therefore fully reflect the complete environmental impact from housing.

What Carlsson-Kanyama (2004) does when studying environmental efficiency and cohousing can be seen as going deeper into the use-phase of a building, and adding a human/ behavioral dimension to it. By showing that cooking collectively in a cohouse reduces the energy consumption required per portion, she also shows that behavior from residents can affect the environmental impact from housing during the use phase.

Departing from the assumption that the use-phase is affected by human behavior and the functional unit (that tries to catch this), this study tries to combine two systems. The first is the system around a building and the second is the system around a person. The focal point is where they overlap, and the system boundaries in this study are set around this area. In Figure 5, this is shown. In this figure, the lifecycle of the building is comprehensively shown as in Figure 4, with a construction phase, a use phase and a demolition phase. On top of that, the lifecycle or system of a person is added. This system is comprehensively shown as having only two processes, housing related consumption and other consumption. In reality, "other consumption" obviously consists of a lot of diverse activities, but since that is beyond the scope of this study, this process is just treated as everything that is not directly related to housing.

Housing related consumption is here assumed to be consumption of housing itself and consumption of services or goods that normally takes place at home and can be related to "meeting the housing needs". This means that factors normally included in a LCA for a building such as heating, water consumption and electricity use are included, but not treated as static factors. Rather they are treated as factors that vary depending on the behavior of residents. On top of that, domestic services such as meals or waste management are included.

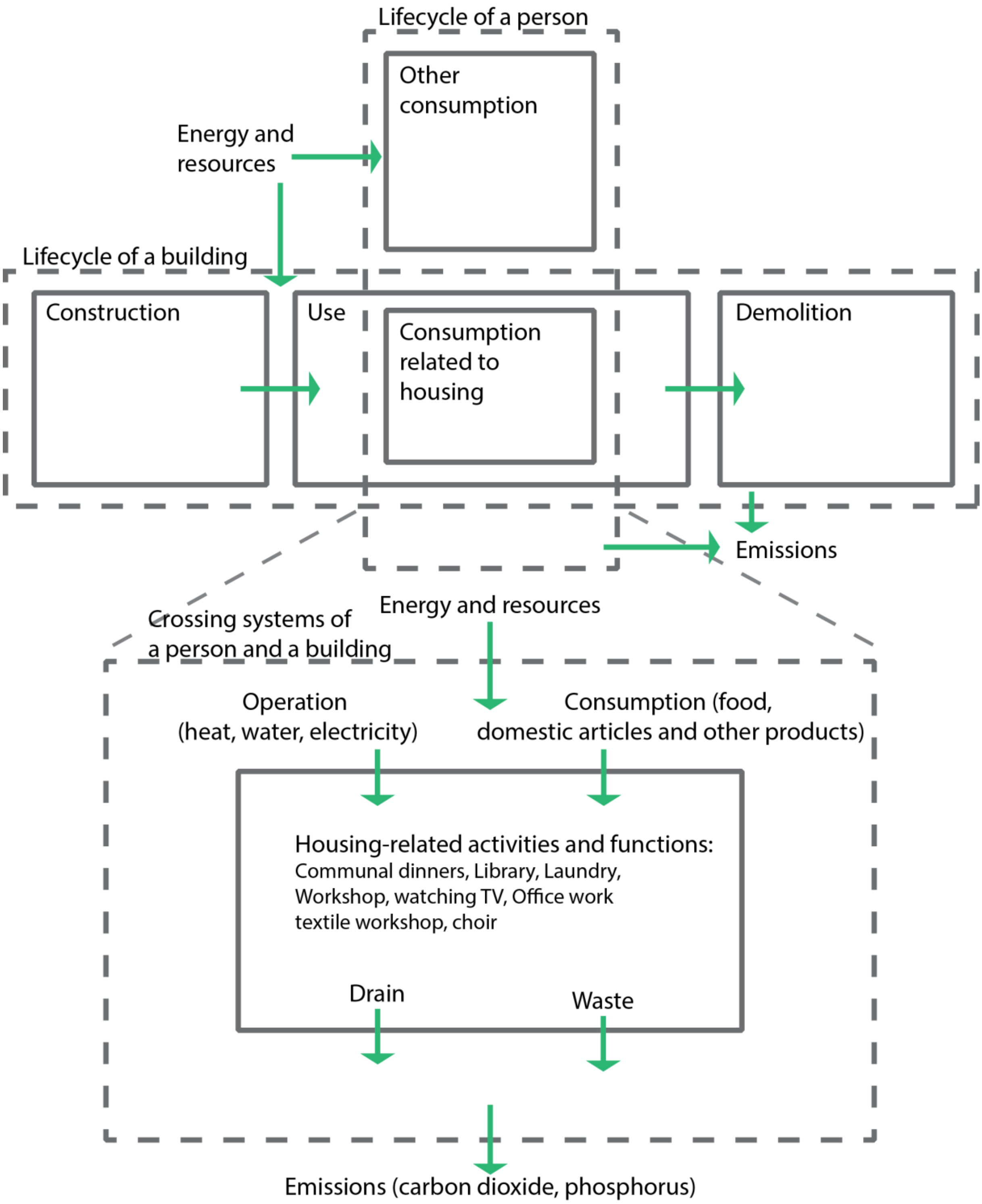


FIGURE 5 OVERLAPPING SYSTEMS OF A BUILDING AND A PERSON, AND A DETAIL OF THE OVERLAPPING AREA.

4.5 The average-alternative

As the case study is constructed, the cohouse Färdknäppen is compared to average housing, in order to see how environmental impact relates. It is preferable to close out factors that will make the comparison less relevant and therefore, the average alternative is built with data chosen to correspond as good as possible to the cohouse in the case study. For instance, most residents in the cohouse are living in single households, and the average age is about 70 years, which is far from the complete national average person. SCB often has statistics divided on different age groups, and in the average alternative, statistics is chosen to correspond to the cohouse' social structure. Therefore, when choosing statistics, data about individuals over 65 year living in single households have been chosen, where possible. The same applies for other characteristics, and it is for instance assumed that a person in the average-alternative would be living in a multifamily house, theoretically located at the same place as the cohouse.

4.6 Processes and activities in Färdknäppen

Having described in section 4.1 how things work in general at the Färdknäppen cohouse, some different processes and activities can be identified, and flows of resources generated by them. A central activity is as mentioned the communal dinners. In terms of inward flows, cooking requires foodstuff, water and electricity for fridges, freezers, stoves and lights. Kitchen utensils, appliances and tableware are also needed. Heating of the kitchen and dining room could also be seen as related to dinners. Dinners also generate drain and waste. The library could be seen as a process or activity that requires books, magazines and newspapers. The library also requires some space that needs heating and electricity that in turn causes flows of fuels. The 4000 piece jigsaw puzzle group works similarly, requiring a puzzle and space with heating and electricity. The sharing of tools is another process that requires a flow of tools. The workshop where tools are stored requires some space, heating end electricity.

As mentioned, most of the communal activities require space. In Färdknäppen there is 345 m^2 of shared space (Kärnekull & Blomberg, 2013). The existence of communal space in itself could be seen as a process or activity, that requires a flow of fuels for energy for heating and lighting, that is part of the cohousing model. Having a large shared spaces is central for social interaction in Färdknäppen and in other cohouses (Palm Lindén, 1992). For instance with activities such as choir practice or evening classes, the communal space is in principle the only resource used. Communal spaces also require furniture, but the turnover of furniture is pretty slow. 3433 SEK were spent on furnishing during 2013 and during 2012, only 585 SEK was spent, mostly on paint and textiles (Kollektivhusföreningen Färdknäppen, 2013, 2014).

In Table 1 below, activities are presented together with flows of energy and/or materials generated by them.

	Flows																
	Operation						Materials										
Activities	Waste	Drain	Water	Heat energy	Electrical energy	Shared space	Other materials	Foodstuff	Books and newspapers	Furniture	TV and computers	Copy machine	Kitchen appliances	Clothing iron	Tools	Sewing machine	washing machines
Communal dinners																	
Library																	
Laundry																	
Workshop																	
watching TV																	
Office work																	
textile workshop																	
Choir practice and evening classes																	

TABLE 1

4.7 Inventory

4.7.1 Food

Information about food consumption in Färdknäppen has been obtained from order lists for food during 2013 and the first months of 2014 and from an interview with the cohouse association's treasurer[16]. Foodstuff for communal meals in cohouse Färdknäppen is bought in two ways. Every second or third week, staple foods are ordered from wholesale company "Martin & Servera". This foodstuff account for about 50 percent of total food consumed in communal meals at Färdknäppen and according to the treasurer in the cohouse, 3000 SEK per week is spent on food from Martin & Servera and 3100 SEK on food from local stores[17]. Groceries are not ordered corresponding to any planned menu or similar, but rather according to the experience of what is usually consumed and if there are discounted prices on particular foodstuff[18]. The other 50 percent of the food is bought by those responsible for cooking. This food is bought from local grocery stores and transported with a "Dramaten"-cart rather than at a super market where you have to go by car[19].

The main source of information about food consumption at Färdknäppen is the order lists to "Martin & Servera". Lists for orders during 2013 have been obtained from Färdknäppen, and the amounts of groceries ordered during one year have been summarized. Similar foodstuffs have been aggregated into categories that can be compared with average food consumption for Swedish adults. For

[16] Person g, treasurer in Färdknäppen, personal communication 26/5-14
[17] Ibid.
[18] Person h, responsible for food orders in Färdknäppen, personal communication 8/4-14
[19] Ibid.

instance Hoki file, Cod and Salmon is merged and treated as "Fish", and the same applies for different root vegetables and similar as well.

An issue was that while order lists to "Martin & Servera" were clear, and possible to obtain, it was harder to get a hold of information about what was bought by different cooking teams. They usually buy what is missing for a certain meal, which generally are fresh vegetables and milk products and other stuff that needs to be fresh, but receipts are usually not saved[20]. However, since costs for food from different suppliers are known and assuming that costs for food generally are proportionate to the amounts, the lists of groceries from "Martin & Servera" can estimated by assuming that the proportions are about 1:1 (based on the proportions of expenses for food). This means that the food bought from Martin & Servera is doubled in calculations used. The principle is similar to the allocation discussed by European Commission et al. (2010), shown in Figure 1 in section 2.5.3. Results from these calculations are presented in section 5.1.

Communal dinners are eaten five nights per week, and not during summer and winter holidays. Because of this, the total number of shared meals during 2013 amounts to 215, which is 59 percent of all dinners a resident eats during a year if dinner is eaten every night. Communal meals are mainly limited to dinners. According to the webpage "Folkhälsoguiden", maintained by the Department for Public Health Sciences & Karolinska Institutet (2009) Institutionen för folkhälsovetenskap & Karolinska Institutets folkhälsoakademi (2009), a dinner should account for 33 percent of daily energy intake. Assuming that energy is evenly distributed in different foodstuff, this would mean that a third of all food consumed by a person is consumed as dinner, or at least should be. If all residents in Färdknäppen participated in all of the communal meals and ate according to the proportions recommended by the Department for Public Health Sciences & Karolinska Institutet (2009), it would mean that around 19 percent (0,33*0,59=0,19) of the total amount of food consumed by a resident was consumed in the form of a communal meals. The reason this is important is because it is only on this share of the total food consumed in the cohouse on which potential positive environmental effects apply. The rest of the food is eaten privately, and assumed to be similar to average in terms of volume and environmental impact.

However, not everyone in Färdknäppen participates in all of the communal dinners. As mentioned, the average number of participants in the shared meals are 35 persons, which is 66 percent of all residents (William-Olsson, 2007). The normal procedure when there are leftovers is that they are sold as food packages. Depending on the routine of the cooking team, there are more or less leftovers, but it is not uncommon that about 5 portions of food are left after dinner and sold as food packages[21]. This would mean that the 35 person participating in the actual dinner needs to be complemented by another group of five persons, indirectly participating in the dinner, making a total of 40 portions per meal. Using a number of 40 portions per meal means that an average of 75 percent of residents in Färdknäppen directly or indirectly participates in communal meals, and thus that 75 percent of the potential environmental gains from shared dinners are utilized, which must be considered fairly high since it is completely natural that resident do not eat all of their meals at home, for instance. With a participation degree of 75 percent in communal meals, it means that

[20] Person h, responsible for food orders in Färdknäppen, personal communication 8/4-14
[21] Person i, resident in Färdknäppen, personal communication 27/5-14

about 15 percent (0,33*0,59*0,75=0,147) of all food in the cohouse is consumed in the form of communal meals.

To get the total amount of food consumed by a resident in Färdknäppen during one year, the food consumed communally is paired with privately consumed food, which is assumed to be the other 85 percent of all food eaten by one person during a year. For this part, average data from Jordbruksverket (2013) is used.

For the average-alternative, data from Jordbruksverket (2013) about average consumption of foodstuff for a person in Sweden has been used. This data tells how much foodstuff an average person consumes per year. Consumption in this case means the amount of food an average person buys, and not how much of it that the person actually eat. This means that waste, such as potato peel is counted, as well as what is eaten, as opposed to statistics from Livsmedelsverket (2012).

Consumption of food creates emissions of carbon dioxide and phosphorus and requires energy to be stored and cooked. Different foodstuff causes more or less emissions, and in "Mat-klimat-listan" (the food-climate list) by Röös (2012), estimations of climate impacts for a variety of groceries are compiled. These impacts are estimations of the total emissions caused by the food, including transportation to stores, processing and production. By combining this data with the amounts of foodstuff consumed, it is possible to estimate the climate impact from this type of consumption.

A list with phosphorus footprints for different foodstuff has not been found. By using statistics from "Livsmedelsdatabasen", maintained by Livsmedelsverket (2014), it possible to estimate the amount of phosphorus in the food consumed by a person in the case study and in the average-alternative. This is the phosphorus that eventually will leave the system around the cohouse with the sewage and with waste. It is important to note that this is not the total amount of phosphorus used to produce the food. Xue & Landis (2010) mean that only about 18 percent of all phosphorus used for agriculture will end up in the foodstuff and Antikainen et al. (2005) propose 17 as a likely percentage for the same thing. Cordell, Drangert, & White (2009) mean that a normal meat-based diet causes 0,6 kilos of phosphorus in direct emissions, and requires 1,6 kilos of phosphorus for agriculture. Other sources of phosphorus in a home could be washing- and dishing detergents, but since 2008 and 2010, phosphates are forbidden in detergents so this is probably a negligible source of phosphorus (Miljödepartementet, 2008, 2010).

4.7.2 Operation

Heating for the whole building is paid for by Familjebostäder, and the same applies for water. Electricity is divided into two parts. One part is electricity for communal spaces, which is paid for by the cohousing association[22]. The other part is electricity for residents own apartments, which they pay for themselves. Data about operation of Färdknäppen has been obtained from the landlord Familjebostäder[23], and by asking residents about their individual electricity use. In total, 10 households gave information about their individual electricity use.

For operation in the average-alternative, national average values have been used. Data for heating comes from Energimyndigheten (2013) and electricity use is based on data from Energimyndigheten (2010) about average use per square meter and year in Swedish multifamily houses. For water, average values from Energimyndigheten (2012) are used.

[22] Person f, resident in Färdknäppen, personal communication 14/4-14
[23] Person j, economist at Familjebostäder, personal communication 9/5-14

Depending on the energy source and the type of flow, climate emissions from different resource use related to operation differ. Gode, Byman, Persson, & Trygg (2009) discuss how to measure climate impact from electricity production. Depending on the purpose of the calculations, different values should be used, and in situations where energy saving is at focus, emissions from "margin electricity" is most suitable. Margin electricity is the electricity from sources that are the most expensive, which are only used when demand is high. In Sweden, this electricity comes from the least sustainable energy-sources such as from coal or natural gas which gives emissions of about 400 g CO_2e/kWh (Gode et al., 2009). When decreasing the electricity use, it is this energy production that will be shut down first, and thus it is most accurate to use these high values when calculating emission-saving potentials.

Färdknäppen is heated with district heating. According to Persson (2008), 55 kg CO_2e /MWh is a good estimate of greenhouse gas emissions from district heating, if the energy comes from a mix of oil, bio fuel and electricity, which seems to be most common. This value is for energy delivered into buildings, which means that it includes heat losses from transmission and distribution.

Production of drinking water also requires energy. In a LCA of drinking water production in Gothenburg it was stated that production and distribution of one cubic meter of drinking water emits 0,1214 kilos of carbon dioxide equivalents (Wallén, 1999). It assumed that emissions from water production in Stockholm do not differ a lot, so the same value is used here.

Treatment of one cubic meter of sewage water in Käppalaverket in Stockholm emits 0,2218 kilos of carbon dioxide equivalents (Erikstam, 2013). Although sewage from Färdknäppen probably is treated at Henriksdals water treatment facility, emissions are assumed to be similar. The amount of phosphorus in the sewage water is dependent on how much phosphorus that enters the system in food. Some phosphorus will leave the system with the sewage and some with waste, particularly with organic waste.

4.7.3 Waste and recycling

Waste from the residents in Färdknäppen is treated in two ways. One part is recycled in a recycling room and the other part is the non-recyclable waste that is emptied with a mobile vacuum collection system[24]. The recycling room was in very good condition and well maintained each time I visited. There were clear instructions on the bins for different fractions, with pictures of what kind of material that was allowed in each bin. The room is located within the building, which means that resident do not have to go outside to recycle. There is also a shelf for reuse in the recycling room, where resident can put things that they do not want which are still functional. Data about the volumes of waste and recycling have been obtained from the landlord Familjebostäder and from the recycling company Ragn-Sells[25][26].

The waste is sorted in the following fractions:

- Newsprint, consists mainly of newspapers and magazines
- Cardboard from paper packaging
- Metal from packaging
- Plastic from packaging

[24] Person k, responsible for cohousing at Familjebostäder, personal communication 5/6-2014
[25] Ibid.
[26] Person l, manager at Ragn-Sells, personal communication 19/6-2014

- Glass from bottles and jars
- Food waste
- Other household waste in bags (treated with incineration)
- Other/bulky waste (treated with incineration)

Stockholms Stad has monopoly on garbage collection for the non-recyclable household waste ("other household waste"), which means that Familjebostäder pays Stockholms Stad for garbage collection. Stockholms Stad then in turn contracts an entrepreneur to do the job[27]. The amount of waste collected this way was calculated using the fee paid by Familjebostäder together with information about fees for garbage collection from Stockholms Stad (2014). Stockholms Stad is basing the fee on the volume of the garbage and to make values comparable, it is useful to have the weight instead, which was calculated using a density of 90 kilos per cubic meter for household garbage, proposed by Brunbäck & Niklasson (2010).

For recycling, data about recycling volumes for April and May was obtained from Ragn-Sells, who collect waste from the garbage room[28]. Ragn-Sells is the entrepreneur since the first of April 2014, and therefore no earlier data is available from them. Since data does not differ a lot between April and May, the values are considered reasonably representative for a year. For food waste, the weight was calculated based on the volume of the bins which are 2*140 liters, which are emptied once a week[29] and a density of 0,22 kilos per liter, proposed by Avfall Sverige (2009). This means that this value might be a bit higher than what is actually true, since the bins are probably not always completely full.

In the average-alternative, data from Avfall Sverige (2013) have been used for recycling volumes, and data from Trafikkontoret Stockholms Stad (2011) for other household waste. Data about recycling is based on national average and data about household waste is based on analysis of actual waste from households in Stockholm. Since this only accounts for waste in bags, numbers for the average generation of "other/bulky waste" have been taken from Avfall Sverige (2013).

To calculate emissions from waste, at least two different methods can be used, that make results differ a lot. One way is to calculate emissions from treatment of waste, but not include the creation of waste. When this method is used, emissions are often calculated with values close to zero, or even negative. Household waste, for instance, is incinerated, and the heat energy is used for heating and electricity. If household waste was not used as fuel, the assumption when using this way of calculating is that some other fuel, such as oil, would be used instead. Therefore the emissions from the alternative fuel is subtracted from the emissions from the waste, since the waste is considered replacing the alternative fuel, which gives negative values for emissions (Palm & Sundqvist, 2010). This is explained further in section 2.5.3. This implies that more garbage decreases the overall emissions, which of course is not true. Most emissions from waste is generated during production and extraction of materials, and if the method with negative emissions is used, emissions of this kind, called upstream emissions, needs to be accounted for elsewhere (Palm & Sundqvist, 2010). In this case, this is partly done with consumption of household related things and food, where values on emissions include extraction and production.

On the other hand, since the upstream emissions are most dominant, it is more powerful to try to decrease emissions from waste by never extract or produce things or materials that will eventually

[27] Person k, responsible for cohousing at Familjebostäder, personal communication 5/6-2014
[28] Person l, manager at Ragn-Sells, personal communication 19/6-2014
[29] Person j, economist at Familjebostäder, personal communication 23/4-2014

be considered waste (Palm & Sundqvist, 2010). It can then be useful to calculate emissions including upstream values, to see the potential for decreasing emissions. By not doing so, it can be seen as if extraction of materials is constant, regardless of use, which is not the case. Considering the ambiguities with calculating emissions from waste, it is also useful to just look at the actual volumes of waste as well.

4.7.4 Other consumption

In Färdknäppen, the yearly communal budget is about 90000 SEK, which per person is about 1700 SEK in communal spending. On top of that, residents' individual household related consumption must be added.

Data about communal consumption is taken from the annual report for the Färdknäppen cohouse association (Kollektivhusföreningen Färdknäppen, 2014). This data indicates how much that was spent on what during 2013 and what the planned expenditures for 2014 are. The yearly budget is always more or less the same, since it is constrained by incomes from membership fees and compensation from the landlord Familjebostäder for maintenance work done by residents[30]. It is therefore assumed that expenditures are similar from year to year and that 2013 and 2014 does not differ a lot from other years. For calculations, the average consumption from the years 2013 and 2014 was used. In the budget for 2013 and 2014 the following were included, among various other things:

- Books, magazines and newspapers for the library
- TV
- Computers
- Copy machine
- Printer and ink
- Treadmill
- Furniture and inventories
- Kitchen equipment
- Cleaning material and consumables for maintenance of shared spaces

Individual consumption for residents in Färdknäppen is assumed to be similar to the average household, but less extensive. Firstly, the communal consumption of various things such as TV or copy machine makes the need for a privately owned corresponding product less, and secondly, the smaller average floor area per person compared to an average household decreases the need for furniture. The average floor area in Färdknäppen, without communal spaces, is about 42 square meters. This is 25 square meters less than the average floor area of 67 square meters per person for a single person over 65 years, or 35 percent less. Based on these factors, a decreased individual household related consumption with 20 percent is probably a conservative estimation.

For the average-alternative, statistics from SCB (2010) about average consumption in Swedish households have been used. These statistics contain average spending from households, divided into several categories. In order to do a proper comparison between the average-alternative and Färdknäppen, those categories in which Färdknäppen spend communal money have been taken into account. This means that if there is a communal TV in Färdknäppen, average spending on TV's have

[30] Person i, resident in Färdknäppen, personal communication 27/5-14

been accounted for in the average-alternative as well. The following categories covers communal household related consumption in Färdknäppen and are used for the average-alternative:

- Furniture, inventories, carpets and textiles
- Household equipment (clothing iron, dishware, tools etc.)
- Radio and TV
- Books, magazines and television license (including newspapers)

The statistics from SCB are presented for different household types, and to make a comparison of individual consumption, a single person household without children best matches an average household in Färdknäppen and have been used for data.

Consumption of other household related things mainly causes emissions of greenhouse gases (among the impact categories studied in this thesis). Räty & Carlsson-kanyama (2007) has compiled a list with carbon dioxide- and energy intensities for a lot of various things, from food to furniture to interest rate. Carbon dioxide intensity is a measurement of the amount of greenhouse gases emitted by consumption of goods or services of for a given price. Räty & Carlsson-kanyama (2007) uses kg CO_2e /SEK and Joule/SEK as units. With knowledge about the amount spent on each category, it is possible to calculate the emissions caused by consumption and how much energy that is used to provide the goods.

5 Results: Environmental impacts from Färdknäppen

Next, results from the LCI and environmental impacts will be presented. The categories of environmental impact that are looked upon are greenhouse gas, phosphorus use and energy use. Greenhouse gas emissions are examined a bit more thoroughly than the other categories, since there are more available data about climate impact for different activities and products, and because everything more or less causes emissions of CO_2e. Phosphorus is mainly found in food, and therefore only discussed there.

5.1 Food

Based on the estimate that dinners should account for a third of everything a person eats (Department for Public Health Sciences & Karolinska Institutet, 2009), it was not possible to see any big differences in total consumption of foodstuff for persons in the two alternatives. A person in the average-alternative consumes around 840 kg of foodstuff each year and a person in Färdknäppen consumes an estimate of 830 kg of foodstuff per year (Jordbruksverket, 2013). Considering individual variations and uncertainties in calculations, the difference is too small to draw any conclusions from in terms of foodstuff consumption. The main reason for the small differences is that although communal meals saves a bit of foodstuff, they only account for about 15 percent of everything that is eaten by a person during a year. This means that any decreased consumption of foodstuff as a result of communal meals only applies on these 15 percent. This makes the leverage on the overall food consumption limited.

In Figure 6 below, emissions caused by food are presented. As can be seen, the overall emissions does almost not differ at all, which is not particularly surprising considering the small difference in consumption of foodstuff.

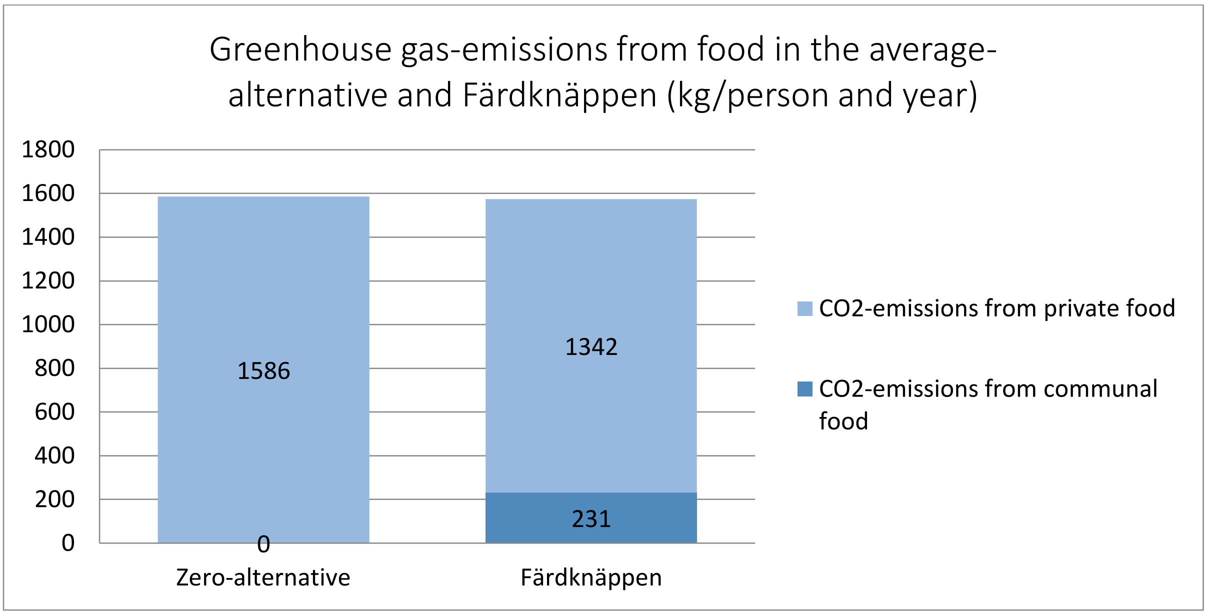


FIGURE 6

In Figure 7 emissions from different groups of foodstuff are presented. What can be seen here is that meat-products cause the majority of greenhouse gas emissions, followed by the dairy-products. Again, no big differences between the average-alternative and Färdknäppen can be seen, which is expected since most residents in Färdknäppen eat as much meat as the average person.

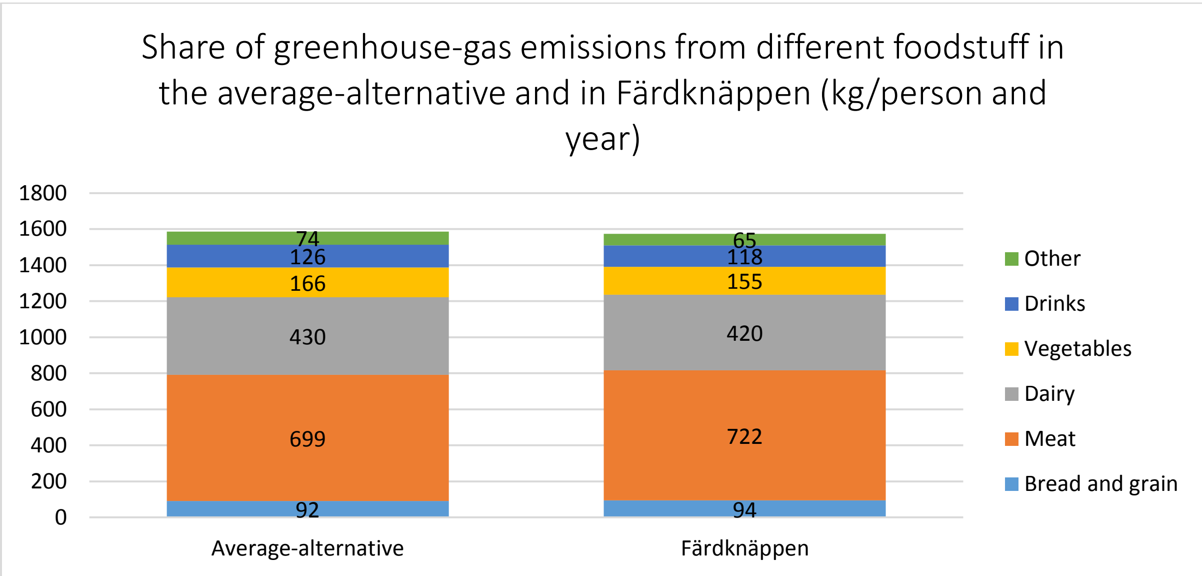


FIGURE 7

In Figure 8, direct and indirect phosphorus use in the average-alternative and in Färdknäppen is shown. Very little phosphorus is accumulated in the human body. This means that the direct phosphorus shown above is the same phosphorus that will enter and eventually leave the system boundaries with the sewage or with waste. There is almost no difference between the average-alternative and Färdknäppen in terms or phosphorus use, and the reason is that consumption of foodstuff is so similar.

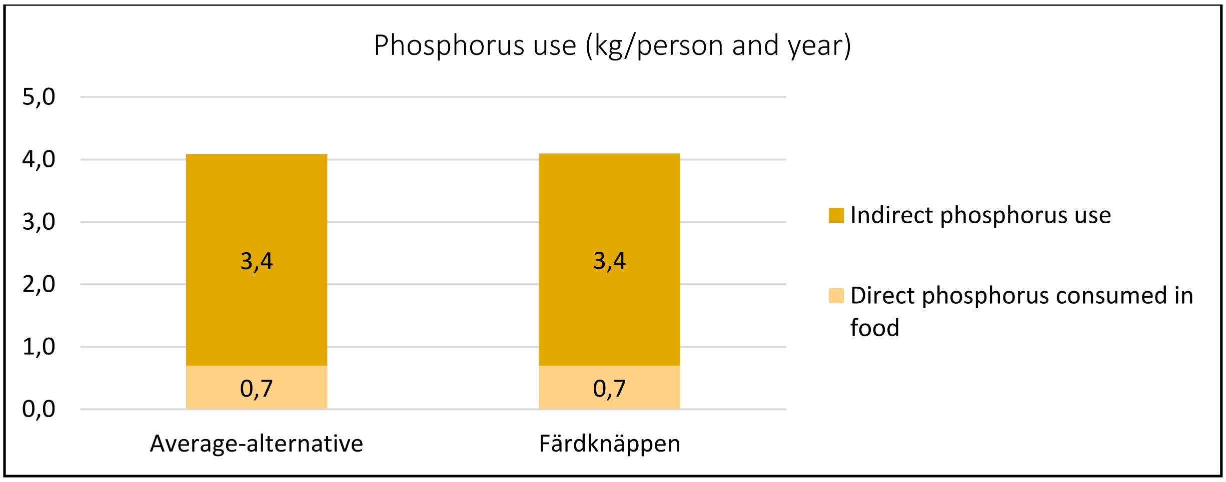


FIGURE 8

5.2 Operation

The total space of Färdknäppen is 2661 square meters, which is 50 square meters per person, including both private and shared space[31]. Energy use for heating in Färdknäppen is 149 kWh per square meter and year and the building is heated with district heating, according to Familjebostäder[32]. Electricity use in Färdknäppen is not calculated by using the floor area but instead by looking at the actual use, which gives better accuracy and. During 2013, the use was 1242 kWh/person and year, including private and communal use. This value was the based on electricity use during 2013 in ten households, plus the communal electricity use. Water consumption in Färdknäppen is 55 cubic meters per person and year[33].

For operation in the average-alternative, average values from different sources has been used. For heating, data from Energimyndigheten (2013) have been used. According to this source, the average energy use for heating in a Swedish multifamily house with district heating is 146 kWh per square meter and year, which is very similar to Färdknäppen. Average electricity use for a Swedish multifamily house is around 40 kWh per square meter and year, according to Energimyndigheten (2010). For a person over 65, living alone in a multifamily house with rental tenure and a firsthand contract, which is what the majority of the residents in Färdknäppen do, the average floor area per person is 67 square meters (SCB, 2008). Estimations of average consumption of water differs a bit, but a common number is 73 cubic meters per person and year, according to Energimyndigheten (2012). It is assumed that all water used will eventually end up in sewage, and therefore the volume of sewage is assumed to be the same as the use of tap water.

In Figure 9 below, energy use for electricity and heating is presented together with floor area. It is evident that energy use for both heating and electricity correlates to floor area in this case.

[31] Person j, economist at Familjebostäder, personal communication 9/5-14
[32] Ibid.
[33] Ibid.

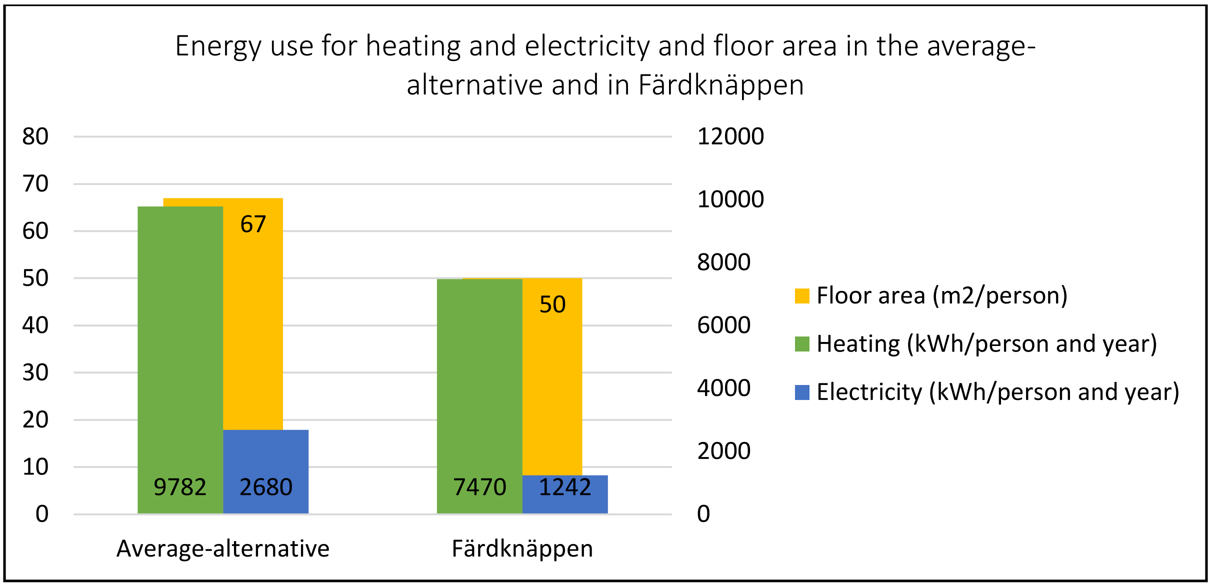


FIGURE 9

In Figure 10 below, it can be clearly seen that there are significant differences in the amount of emissions from operation between the scenarios. A resident in Färdknäppen uses a lot less electricity compared to an average person in the average-alternative, which results in about half of the emissions of greenhouse gases for electricity production. Emissions from heating is also lower for a resident in Färdknäppen, which mainly depends on the smaller floor area per person, since energy use per square meter is almost the same for both scenarios. Although different in terms of volume, water use and drain does almost not at all contribute to the overall emissions of greenhouse gases.

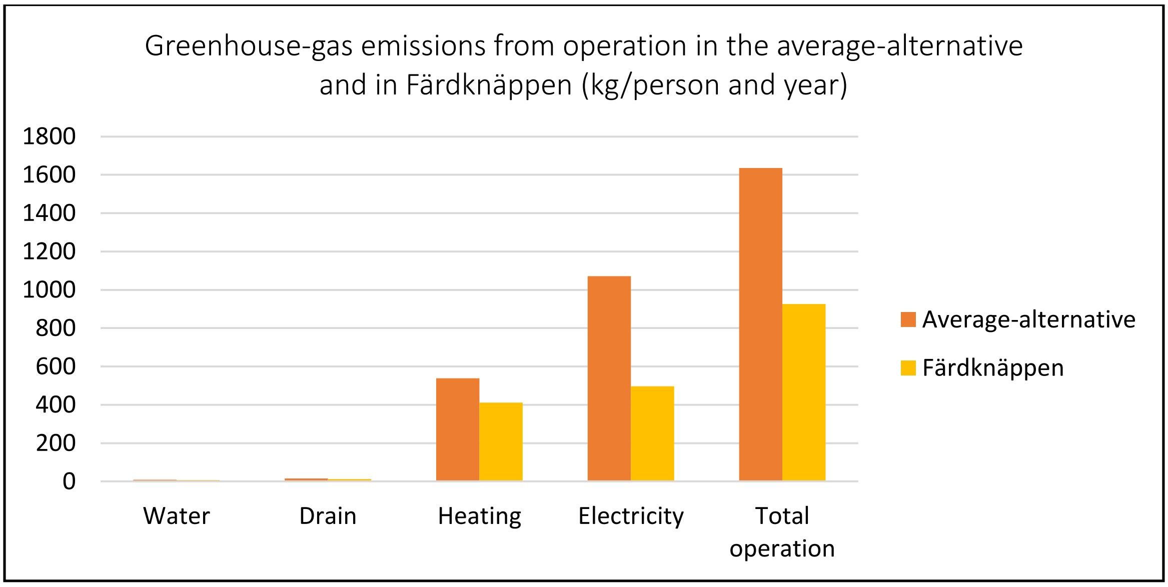


FIGURE 10

Electricity use is significantly lower in Färdknäppen than in the average-alternative, which is interesting. As Carlsson-Kanyama (2004) show, communal cooking requires less electricity per person, which can explain the low values. According to the energy company Eon, cooking normally requires 400 kWh per household and year, and refrigerator and freezer requires around 1000 kWh. A dishwasher takes around 200 kWh per household and year (Eon, 2013). Together, cooking related activities use more than half of all electricity used in an average household (Eon, 2013). This is very interesting since electricity use per person in Färdknäppen is somewhere around half of the average. Although a relatively small share of all food consumed by a resident in Färdknäppen is consumed in the form of a communal meal, the shared meals replaces the dinners which probably are the most energy-consuming meals to cook. This is assumed since a dinner often consists of hot food, while breakfast often does not, and lunch is often not eaten at home. Many residents in Färdknäppen are retired though, which might mean that lunch is eaten at home, but it is common to either eat leftovers from yesterday's dinner, or to keep to sandwiches or other cold food[34][35]. Electricity for freezer and fridge is a big share of all electricity used, and this part is not directly related to how much food that is cooked using the stove. Carlsson-Kanyama (2004) means that storing food requires more energy in a cohouse with shared meals than in a conventional house, since each resident have their own fridge and freezer, plus a share in the communal dittos. This is however based on the assumption that private fridges and freezers do not differ in terms of energy use, compared to the average. In Färdknäppen, private apartments are equipped with a combined fridge and freezer unit, which is half the size of the relatively common solution with two separate units. To have a smaller kitchen than average, including smaller appliances was an active choice from the cohousing association when the building was designed. A problem however was that national norms at the time required fully equipped kitchens, but fridges and freezers are as small as allowed[36]. Therefore, it is likely that they in fact contribute to the low electricity use, as opposed to what Carlsson-Kanyama (2004) means.

5.3 Waste

In Figure 11, amounts of different fractions of waste are shown. In total, a resident in Färdknäppen generates an estimate of 410 kg of waste and recycling per year. This is slightly more than the 380 kilos per person and year that the average person in Stockholm generates (Avfall Sverige, 2013; Trafikkontoret Stockholms Stad, 2011). Generally, residents in Färdknäppen recycle more than the average person, but they also generate more waste in total. A big difference is the distribution of non-recyclable waste, where residents in Färdknäppen generate very little household waste (bagged waste) compared to a person in the average-alternative, but on the other hand a lot more "other/bulky" waste. It should be noted that high values on different categories of recycling is not per se a bad thing, since it probably means that the degree of recycling is high, at least if other waste generated is lower. This however does not seem to be the case in Färdknäppen, where "bulky waste" is making the total amount of waste higher than average.

[34] Person i, resident in Färdknäppen, personal communication 27/5-2014
[35] Person c, resident in Färdknäppen, personal communication 31/3-2014
[36] Person m, resident in Färdknäppen, personal communication 27/5-2014

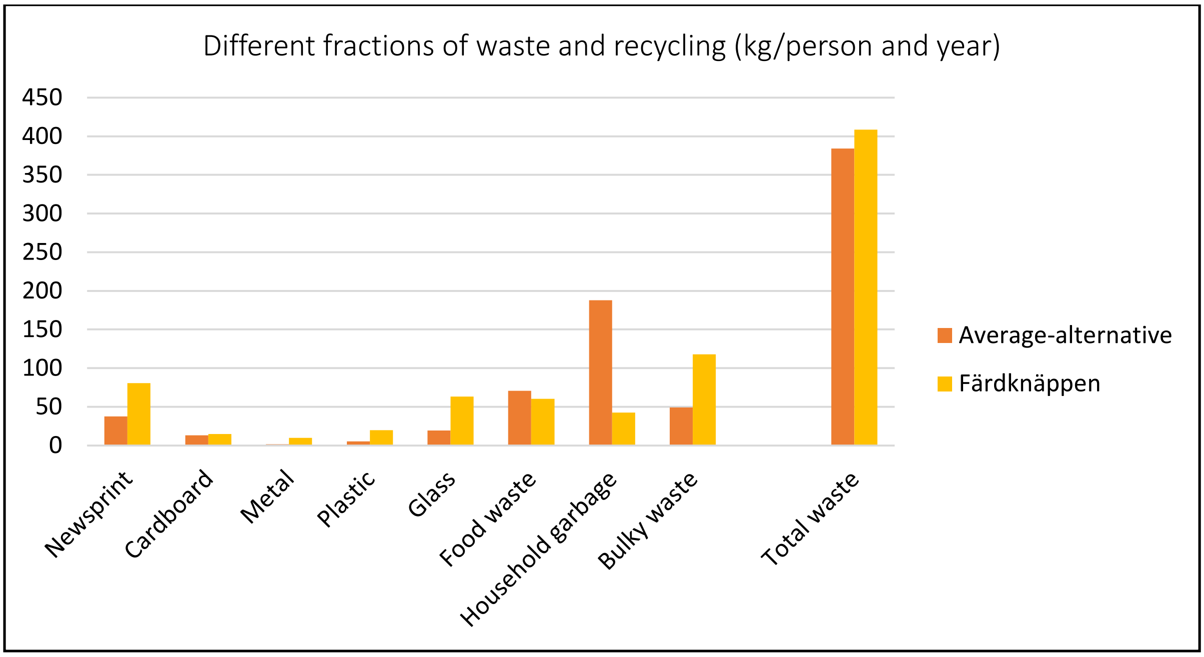


FIGURE 11

In Figure 12, emissions of greenhouse gases from waste, including upstream emissions, are shown. What is interesting is that even if residents in Färdknäppen generates more waste than an average resident in the average-alternative, emissions of greenhouse gases are lower. This is mainly because the degree of recycling is higher in Färdknäppen than in the average-alternative. It should be noted that by using this way of calculating, some emissions are counted twice, since they are both accounted for in the (upstream) waste calculations, and in its own category. Still, for the purpose of comparing two scenarios this is of less importance since the same applies in both cases and does not cause different results.

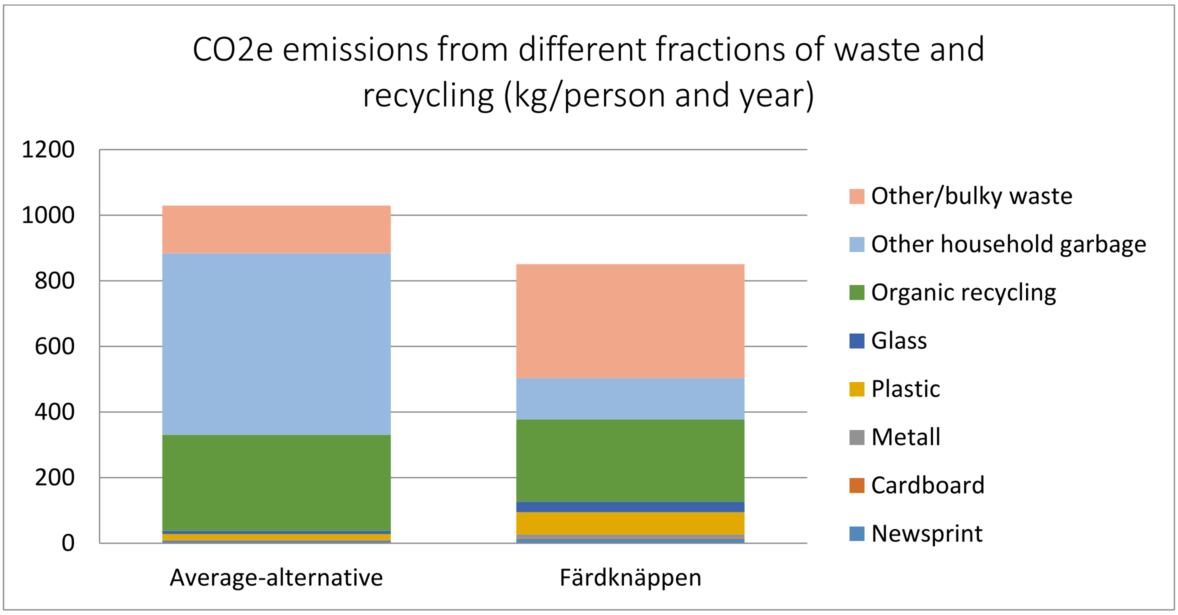


FIGURE 12

Sanne (2012) talks about so called rebound effects, which he exemplifies with less fuel consuming cars. Such cars, he means, might encourage the owner to drive more, since the cost per distance is lower. This might lead to a situation where emissions in the end does not change or even increases. A risk with cohousing is that it will have rebound effects too. A more efficient home with less floor area might be cheaper, which in turn gives residents more money to spend on other things. If this money is spent on consumption of material goods, it is likely that it this consumption would result in more waste, eventually. Considering the relatively small differences in volumes of waste, this is not obvious in the case of Färdknäppen but could partly be a possible explanation.

5.4 Other consumption

Below, emissions from household related consumption is presented, calculated based on the carbon dioxide intensities presented by Räty & Carlsson-Kanyama (2007). As can be seen in Figure 13, there are no significant differences in emissions from total consumption of household related goods, based on the assumptions about 20 percent lower private household related consumption I Färdknäppen. Total household-related consumption is very similar in both alternatives. For household equipment, consumption is even higher in Färdknäppen than in the average-alternative, which most likely is because a resident in Färdknäppen has their own kitchen, plus a part of the shared kitchen, thus having more kitchen facilities in total than an average person.

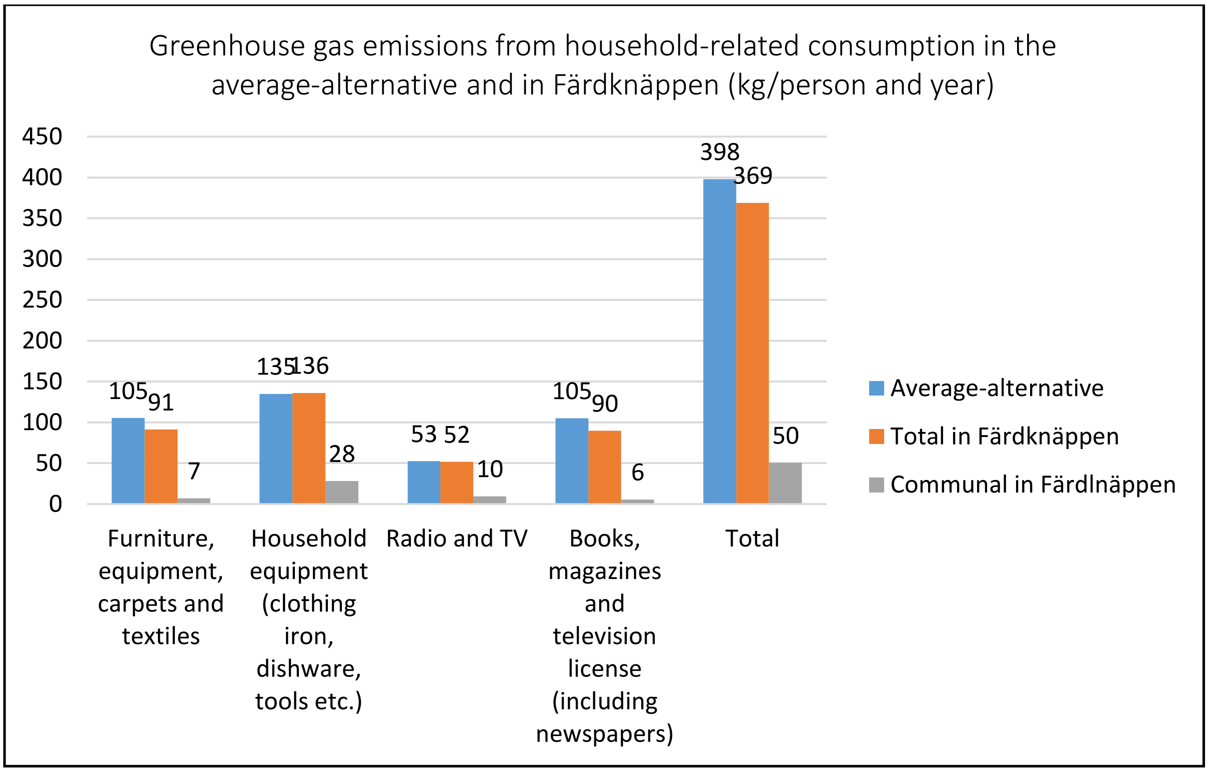
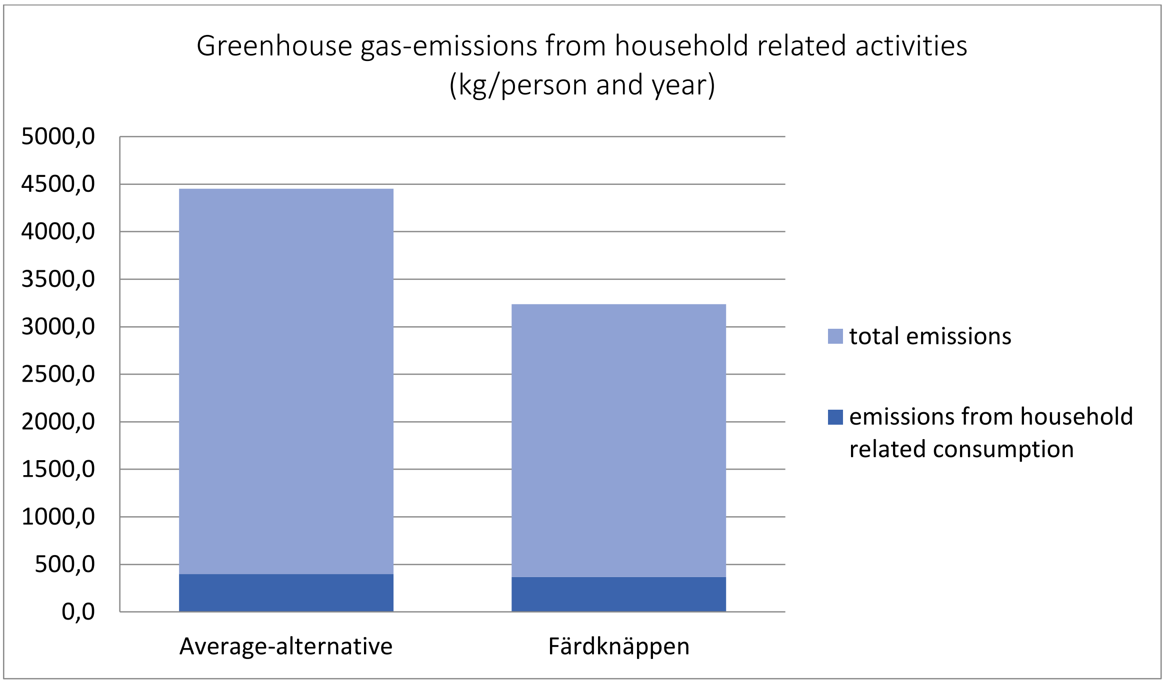


FIGURE 13



In Figure 14 below, the impact of emissions from household-related consumption is shown in relation to the overall emissions from housing for one person during one year, which is relatively low. This makes any savings of household-related consumption less influential on the overall environmental impact from housing, even if the saving is substantial in itself in terms of percentages.

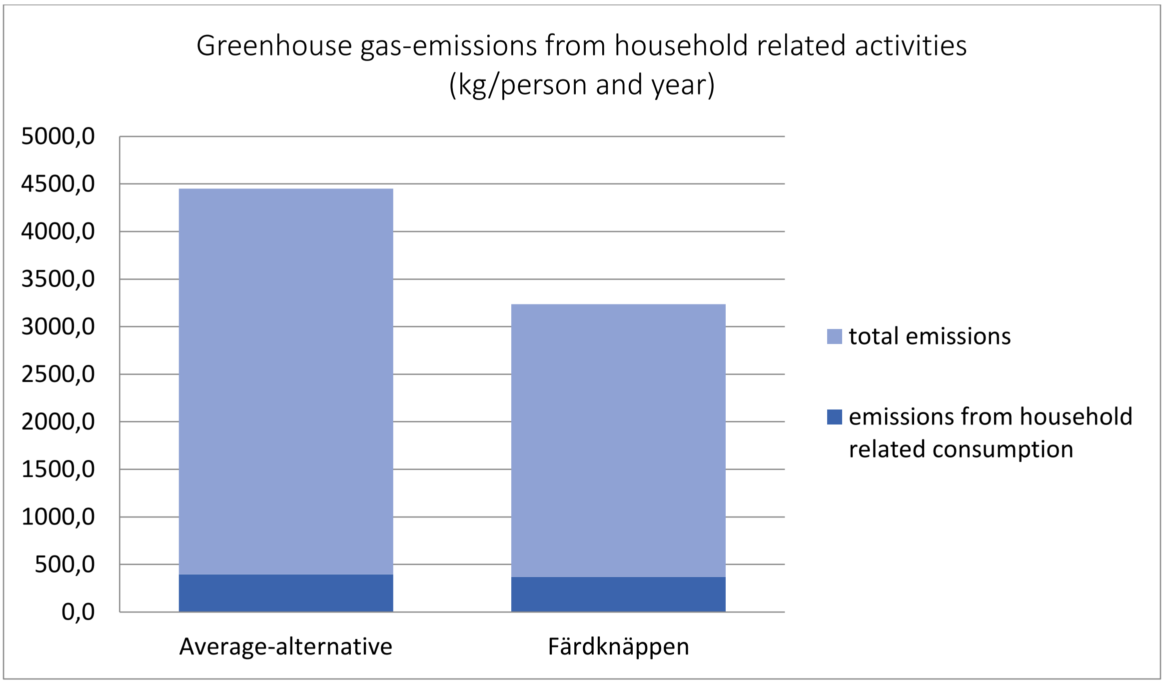


Figure 14

5.5 Total

In Figure 15, all impact categories are shown. It is clear that operation and food causes most emissions of greenhouse gases in both scenarios. Waste also contributes significantly, mainly because emissions shown in the above figure are calculated including upstream emissions, which emphasizes the importance of consumption in general, since waste is a good indicator of how much residents consume. However, no significant difference in the amounts of waste could be seen between the two scenarios. Household related consumption is in the context a small factor, which makes decreased household consumption less influential to the overall impact. Consumption of foodstuff causes almost the same amount of greenhouse-gas emissions for both alternatives, which means that operation is the single major differing factor. In total, the difference in emissions between the two scenarios is almost one ton of greenhouse gases per person and year, which mainly depends on the lower energy use per person, resulting from shared space and communal cooking.

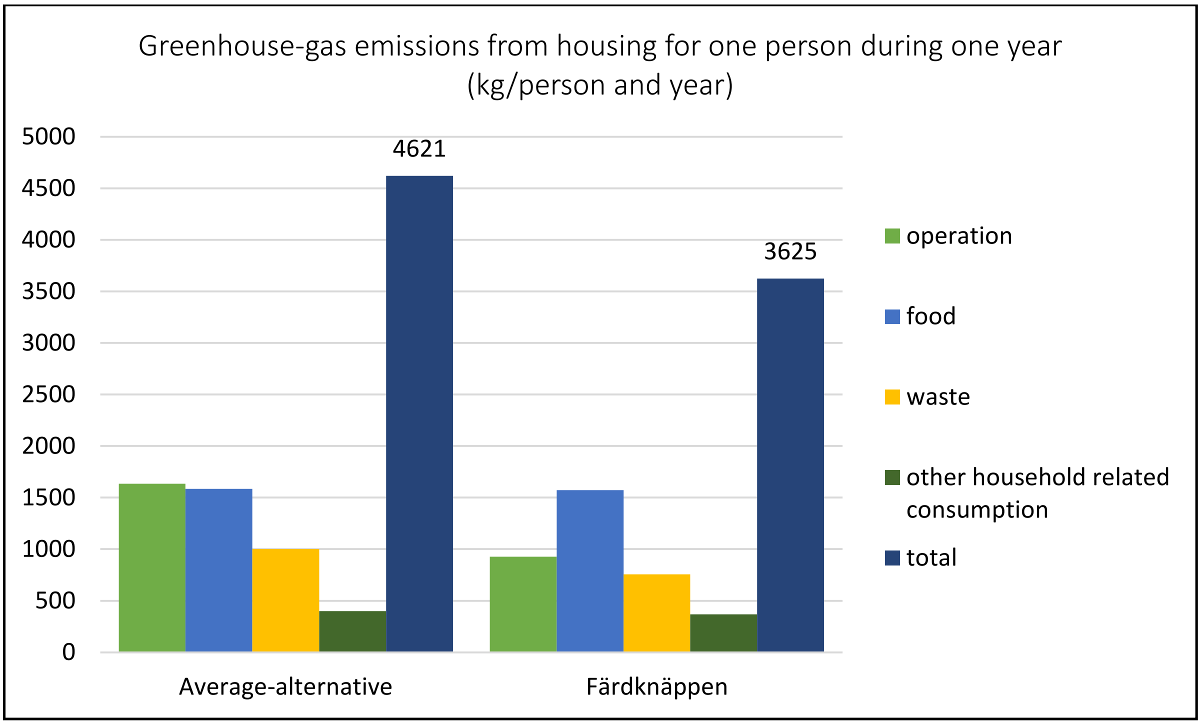


FIGURE 15

6 Discussion

6.1 Resource flows and cohousing

Going back to one of the research questions of this thesis, it asks *how resource use in a cohouse differ compared to in a corresponding average home in Sweden and to what extent can potential differences be related to the type of housing.* The short answer is that resource use in a cohouse is lower, at least in the Färdknäppen cohouse. Most of the saving comes from lower energy use for operation, and in turn, this is related to the type of housing.

Central with the cohousing idea are the shared spaces, and although residents in Färdknäppen have quite a lot of floor area per person, it is still less than what an average person in the same age living in a conventional multifamily house has. Space in itself does not use any resources during its use phase but it requires heating and electricity to be comfortable which requires resources. Energy use for heating and electricity in Färdknäppen was significantly lower than in the average-alternative, which makes flows of resources smaller. At least for heating energy, this was clearly related to the smaller floor area per person, and the smaller floor area per person to some degree relates to the type of housing, which in the case of Färdknäppen is built and designed with the purpose of making it easier to get by with less floor area. Smaller floor area is likely to also affect other flows. A smaller apartment obviously requires less furniture and probably less electricity because it needs less lighting, which also affects the flows of resources. And even if anyone can live smaller, cohousing makes it easier to live smaller without getting overcrowded, for instance with shared guestrooms and other shared spaces than can compensate the smaller private floor area. It can therefore be said that the type of housing is related to the floor area which in turn affects the volume of resource flows.

Waste flows did not differ significantly, which indicates that the amount goods consumed are similar in both scenarios. Consumption affects several flows of material and causes emissions, and based on for instance Vestbro (2012) who claims that cohousing makes it possible for residents to consume less, this was a bit interesting. So while there for this category was reason to believe that the housing type affected the use of resources, it seems like it did not. Also, it turned out that consumption of household related things causes relatively small flows of resources, compared to the direct energy use of the building. So regardless of if there is a lot of influence from the type of housing on the consumption, it does not affect any major resource flow, compared to flows related to food and operation.

The functional unit was defined as “meeting the housing needs for one person during one year”. This formulation is obviously open for different interpretations, which was useful. By formulating it this way, it highlighted that the different ways people live affect their environmental impact. For a billionaire, nothing less than a 2000 square meter palace might be meeting the housing needs, because of this person’s preferences. For a student, a 10 square meter dorm-room and a shared kitchen might do. Obviously, the student’s household related emissions will be many times lower than the billionaires in absolute terms, even if the palace is built to passive house standards. By not making “housing needs” a static factor, it became more evident that the type of housing (whether being cohousing of a kind or a conventional home) and peoples view of what constitutes sufficient housing, is as important as the technical specifications of a home in order to decrease resource flows and the environmental impact.

6.2 Is cohousing environmentally sustainable?

As Wangel (2013) discuss, the concept of sustainability is often divided into categories of social-, economical- and environmental sustainability. This work has mainly been concerned with environmental sustainability, which in Wangel's view is the easiest one to assess, since there are quite clear threshold values that consists sustainable levels of emissions. For greenhouse-gases, Wangel (2013) states that one ton per person and year would be sustainable, if everyone globally had a similar impact. This means that a person living in Färdknäppen, as well as more or less any other person in Sweden, is far from living an environmentally sustainable life. Residents in Färdknäppen causes emissions of in the order of 3,6 tons of greenhouse-gases per person and year from housing, food and other housing-related consumption. On top of that, they consume a lot of other things, like most other persons in Sweden. But on the other hand, residents in Färdknäppen saves up to a ton of greenhouse gas emissions per person and year compared to a resident in the average-alternative, which has to do with the way they live. An average person in Sweden causes total emissions of about 10 tons of greenhouse gases per person and year, if everything that is consumed is included (Sanne, 2012, p. 44). In relation to that, a saving of one ton is about ten percent, which is substantial. It therefore seems like cohousing, at least in Färdknäppen, is a way towards a sustainable level of emissions. In the longer run, this saving is not enough, but it is a step in the right direction.

In Sweden, there are around 40 cohouses, which is in the order of 0,1 percent of the housing stock. Would it be a good strategy to increase this share in order to increase the environmental sustainability of the housing stock overall? The example of the cohouse Cigarrlådan in Hökarängen in Stockholm shows that it is doable to convert an existing building into a cohouse. This means that it would be possible to increase the share of cohouses in the housing stock, without adding new buildings, which as Sanne (2012) discuss requires more resources than using the existing stock more efficient. Considering the lower environmental impact per person for someone living in a cohouse, it seems like a good idea to live this way, at least from en environmental point of view. But it would also be possible to introduce certain elements of the cohousing idea to a wider audience. For instance, in Färdknäppen there are some people not living in the cohouse who still participates in the shared meals. This means that they gain the environmental advantage from shared meals, in the form of lower energy use, without living in a cohouse. In some way, it might be possible to enable people in conventional homes to cook together to a larger extent. The same goes with sharing and reuse of products. Any multifamily house could possibly have a system for reusing and sharing things similar to what is common in cohouses. Although the environmental gains from this are not major, it might be more important in a future where other efforts are already taken.

6.3 What matters and what can be changed?

Both Sanne (2012) and Wangel (2013) discuss the low turnover of the Swedish housing stock, and states that something must be done with the existing housing stock in order make it more sustainable. Cohousing decreases environmental impact from housing for a person, but not enough. It is therefore interesting to discuss what could be done in a cohouse and in the existing housing stock to further decrease greenhouse-gas emissions. From this point of view, it is useful to look at the importance of different categories of emissions and what is causing them. In this study, it is clear that food and operation are the major sources of emissions. If trying to make to make all types of housing, including cohousing, more efficient, where should efforts be made then? In order to test this, some different hypothetical, but fully realistic, scenarios are tested to see what has an impact on the overall result

6.3.1 Decreased floor area

Operation is one of the most influential factors on overall household related emissions, and since it so directly connected with the floor area, the easy way to decrease these emissions is to decrease floor area per person. Again, this applies not only on cohousing, and as Sanne (2012) discuss, this could be a way to increase the efficiency of the whole housing stock. For instance, as the scenario in Figure 15 shows, by decreasing floor area with half in the average-alternative, down to the EU-average of 34 square meters per person, almost the entire difference between the average-alternative and Färdknäppen disappears. In one way, it could therefore be seen as if living in Färdknäppen is a way to live a bit more spacious and still not increase ones environmental footprint. Although the floor area per person is not as easy to change as ones diet (although some people surely thinks the opposite), it is easier to change than for instance converting an existing building into a passive house. Consuming less household related things is of course relatively easy, but it will not affect the overall housing related emissions as much as other categories and the same apply for water.

The biggest source of housing-related greenhouse-gas emissions for a resident in Färdknäppen is the energy use for heating and electricity. Although floor area per person is smaller for residents in Färdknäppen compared to average floor area per person in the average-alternative, floor area person is generally very high in Sweden, which is something Sanne (2012) discuss. An interesting scenario to test is to decrease the floor area for someone in Färdknäppen down to the EU-average. This means going from 50 to about 34 square meters per person (SCB, 2012). Practically, this would mean living more people in Färdknäppen which would mean less single person households. In Figure 15, the effects of such scenario can be seen. The only thing that is changed is the floor area, which in turn affects energy use. In this scenario, emissions from operation are lowered with a bit over 100 kg at a price of a bit less floor area.

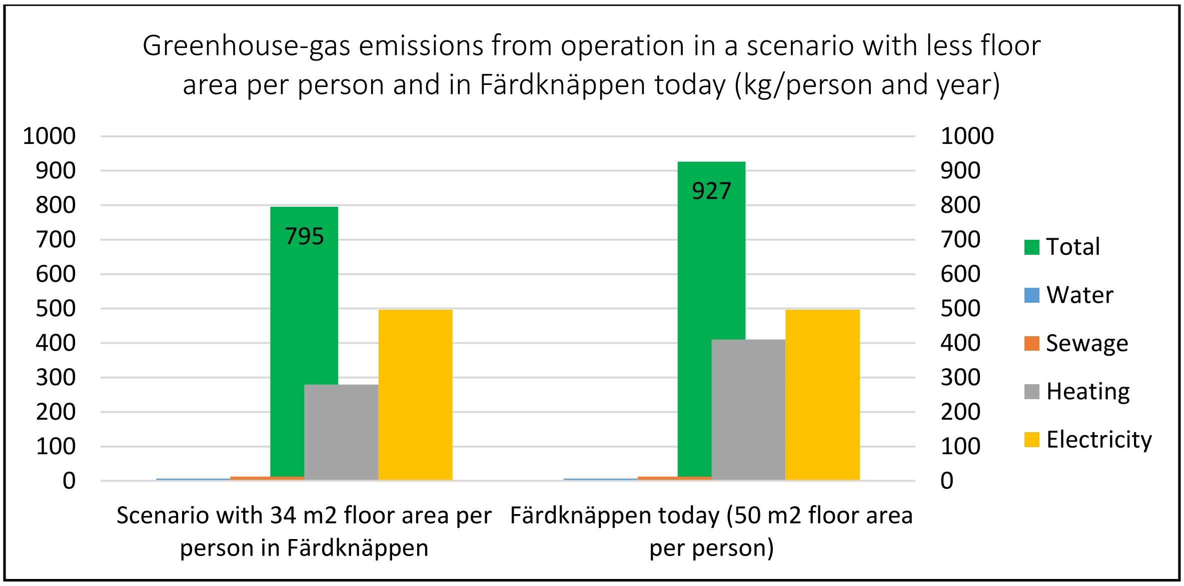


FIGURE 16

6.3.2 Vegetarian food

The amount of foodstuff is clearly, and maybe not so surprisingly, hard to affect. After all, people need to eat a certain amount of food. Food waste can maybe be affected, but as it seems, this is no major source of emissions in relation to the overall impact from food that is actually eaten. In Färdknäppen, about 60 kg of organic waste is thrown each year, which is less than 10 percent of what a person eats during one year. A lot of this waste is also things such as potato peel and other things that is not considered edible. But by changing the diet, there are apparently a lot of emissions to be saved. In the vegetarian diet scenario, shown in Figure 16, it can be seen that by choosing a vegetarian diet, emissions from food decreases with about half a ton. This decrease has nothing to do with the type of housing, it should be noted, and can be used anywhere and still be effective.

As was seen in the results, consumption of foodstuff is an influential factor on the overall environmental impact. Of the different categories of foodstuff consumed by someone in Färdknäppen or an average person, meat causes the most emissions. In Figure 17, a scenario where all meat consumed by a person in Färdknäppen is replaced by a doubling of vegetables is shown. Based on what Livsmedelsverket (2014b) recommends for vegetarians, this represents a vegetarian diet where the main source of protein is different vegetables and some milk products. The figure show that such a diet is a more effective way to decrease emissions from consumption of foodstuff than the relatively small savings that the communal meals provide. The scenario also shows the importance of choosing a certain diet in relation to other household related saving efforts. Emissions counted in this scenario is however only from production of foodstuff and does not take into account cooking, which might play a significant role in terms of energy use, as discussed earlier.

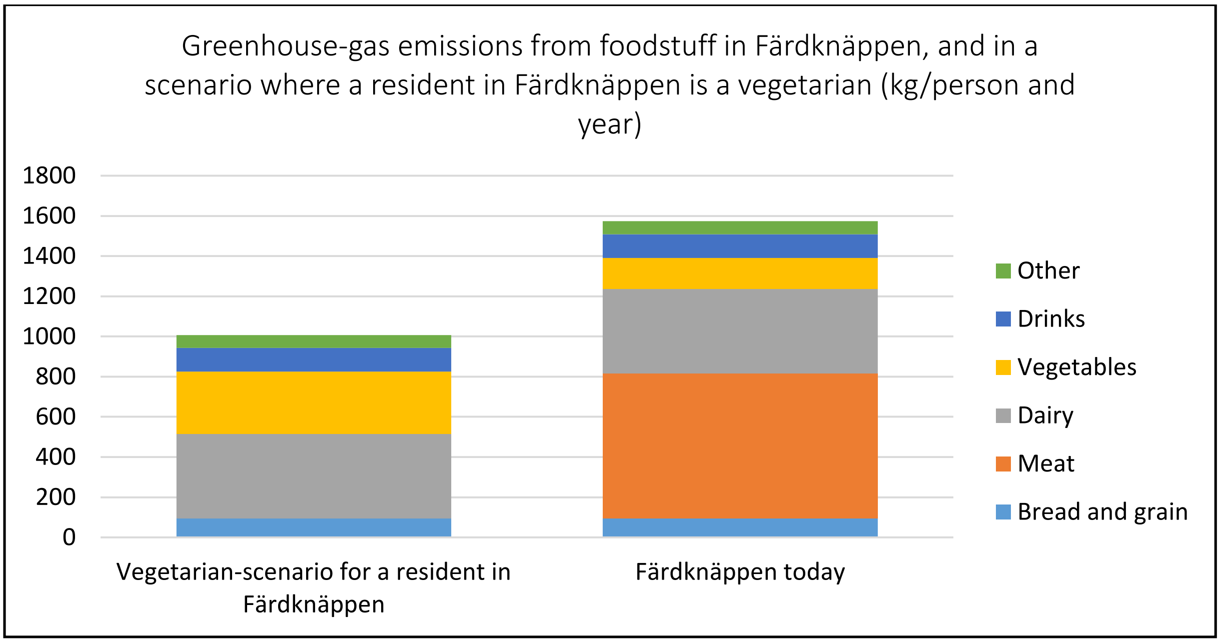


Figure 17

6.3.3 Less household related consumption

Today, it is common among residents in Färdknäppen to own things privately despite that they also have access to a corresponding thing communally in the cohouse, for instance with computers or TVs. At least theoretically, it would therefore be possible to consume less of such things without losing the functionality they provide. In Figure 18, a scenario is tested where all potential gains from communally owned goods are utilized. The idea is to test how much impact it would have on the overall environmental impact if residents would refrain from owning things that they also have access to in the form of a communal corresponding thing. Consumption of furniture and household equipment is assumed to be 20 percent lower than in the average-alternative. Since everyone in Färdknäppen have fully equipped apartments it is unlikely that these categories of consumption can get a lot lower. However, with radio, TV, computers, books and magazines, it is at least in theory possible to decrease the private consumption of these to a minimum, and still have the functionality in the form of shared resources. To test the scenario, that kind of consumption is assumed to be 90 percent lower than for a person in the average-alternative.

Results show that such scenario decreases emissions of greenhouse gases from household-related consumption with about 110 kilos, down to about 260 kilos per person and year from 370 otherwise. Put in relation to the overall emissions from housing and related consumption, this difference is rather low, which can be seen in Figure 17. To reach emissions of one ton per year, all possible efforts needs to be done though, and 100 kg CO_2 per person and year is in relation to the sustainable level of 1 ton per person and year a not negligible amount.

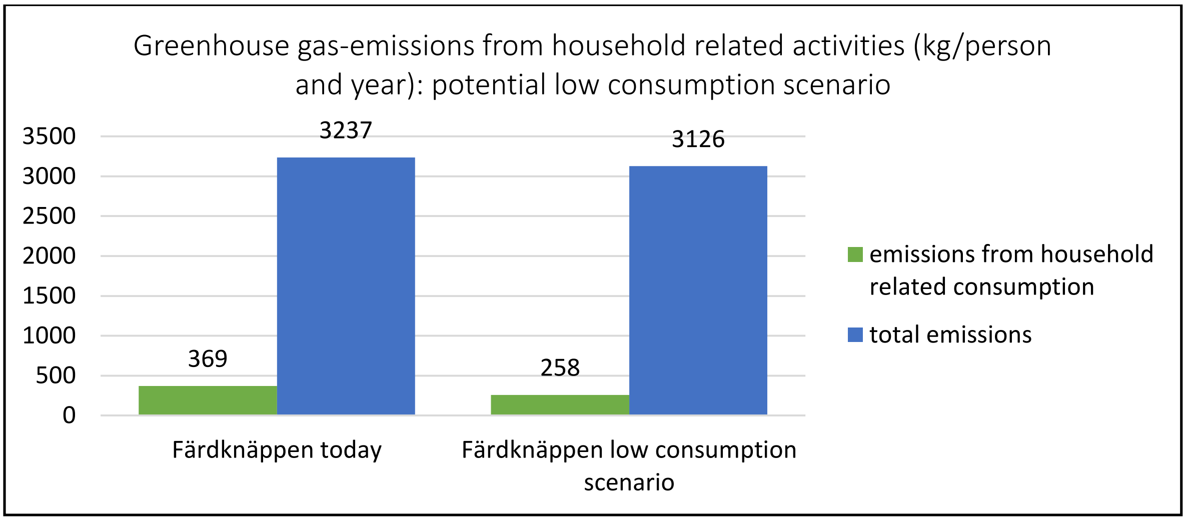


Figure 18

6.3.4 Vegetarian diet and less floor area combined

In the One Tonne Life project, discussed in section 3.1, the test family managed to lower their emissions from housing and food to 2 ton of greenhouse-gases per person and year. This was at level where they could accept the standard of living long term. If a resident in Färdknäppen combined the savings efforts discussed in the scenarios above, which means decreased floor area per person and a vegetarian diet, emissions would drop significantly to just under 2 tons per person and year (see Figure 19). This is only emissions from operation of their home and from food in order to make the comparison with the One Tonne Life project accurate.

Although less space and no meat would, at least according to some, mean a decreased living standard, it shows that there are different ways to lower a person's environmental impact. The One Tonne Life represents a technology-focused and probably expensive alternative that is hard to apply on the existing housing stock, while the low potential scenario in Färdknäppen represents a completely doable approach that would cost residents less and can be applied in the existing housing stock without major reconstruction. It would also be possible to combine technological development with a substantial change in behavior, but it takes a lot of effort to apply all the energy saving technologies to the existing housing stock, which makes a behavioral change seem easier.

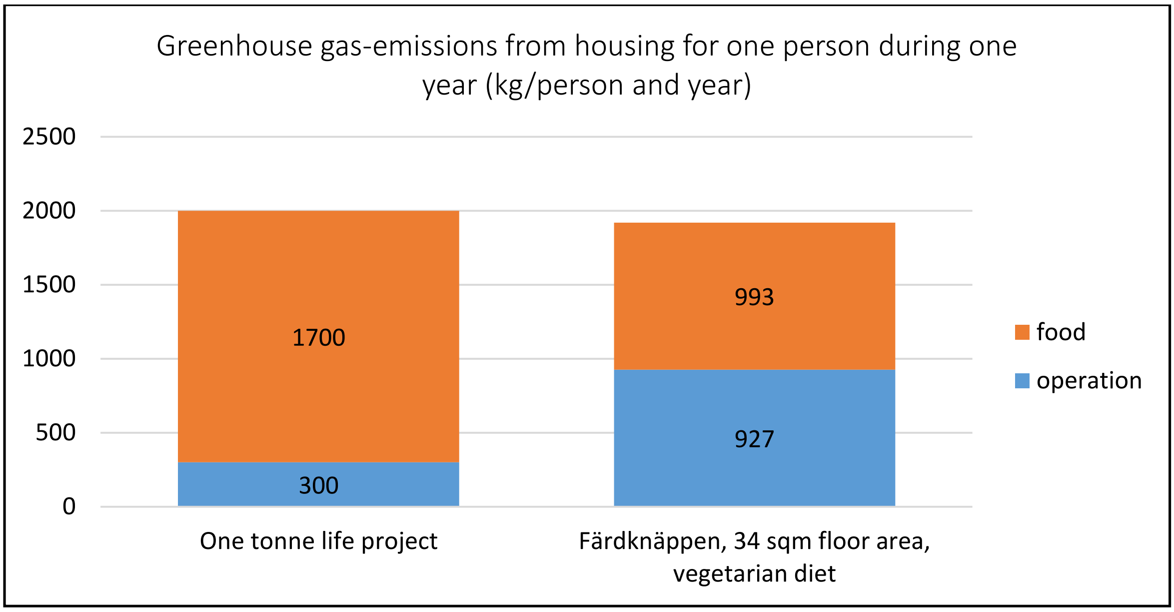


FIGURE 19

Going back a bit to the lifecycle approach, one should also ask if saving about a ton of greenhouse gases per person and year matters for the overall impact of a building, including construction and demolition. According to a LCA of a passive house in Norway by Melvær (2012), the impact from the use phase of this building accounts for 69 % of the emissions of greenhouse gases from the building during its full lifecycle, that is calculated for 50 years. This is for passive house and the use phase is likely to contribute to an even bigger share of the emissions from a conventional building. So clearly, the use phase is important. The passive house in Norway caused emissions of 1,9 tons of CO_2e per square meters during its 50 year lifecycle. In order to compare this with the savings from Färdknäppen, the one ton saving per year can be calculated into a value per square meter, which is then about 0,93 tons of saving per square meter during 50 years (50 years* ~50 residents* ~1 ton CO_2e saving/2661 square meters flor area). Although the complete emissions from Färdknäppens full lifecycle are unknown, and most likely a lot higher than for the norwegian passive house, it is still interesting to compare the numbers, and seemingly, the savings related to Färdknäppen being a cohouse are not a neglible part of the buildings complete impact during its lifecycle.

6.4 How can cohousing be promoted?

Considering the seemingly good environmental performance of cohousing, it would be positive if this type of housing constituted a larger share of the overall housing stock. How could establishment of more cohouses be reinforced then?

Currently, there seems to be a lot of interest among construction companies and developers to create so called sustainable housing. As discussed, the focus in these cases is mainly on technology. But what this shows is that actors involved in this have something to gain from involving in "green" projects and marketing themselves as environmentally concerned. Assuming their motives are profit, or goodwill, it means that there is a demand for sustainable homes. At the same time, cohousing, which is a very good alternative approach to sustainable housing, does not get as much attention. If cohousing to a larger extent was labeled as green and sustainable, it is possible that there would be more interest in cohousing from actors influential over housing construction. Also, a problem today could be that cohousing still is seen as a bit too alternative for "common people". To get rid of that image is complicated, but with more cohousing, the type of housing will likely be seen as less alternative. Also, with more knowledge about the environmental gains from cohousing, for instance from works like this, it should be easier to argue for cohousing as a different path towards sustainable housing, and in the longer run to make developers, planners and decision makers more interested in this solution.

With the current economic system and the way the housing market works, there are probably at least two main obstacles for cohousing to grow. First, cohousing is preferably organized with rental tenure rather than in the form of housing cooperatives. Without going too deep into the driving forces behind it, it can at least be seen quite clearly that rental tenure has been less popular among developers in Stockholm and elsewhere. Secondly, a landlord wants to maximize profit, even public housing companies in Sweden needs to work according to such principles. With maximized return as their main goal, landlords needs to rent as much space as possible, and it is probably harder to rent 40 private square meters plus 20 shared than solely 60 private square meters, especially when cohousing is seen as a bit weird by most people.

Other obstacles for cohousing are possibly to be found in building regulations. When Färdknäppen was built, regulations required a fully equipped kitchen, while this was not needed since the communal kitchen is available for the residents. This was something that current regulations at the time could not handle, and although regulations probably have changed, there are probably still mainly adapted to the way the majority of housing is built.

Up to this point, most cohouses have been created by a housing company with more or less input and cooperation with future tenants. This, of course, requires a housing company to be interested in working with a project like this. The German baugemeinschaft could potentially be a way to circumvent this issue. For instance, a group of people interested in living in a cohouse could go together and work directly with an architect and a construction company to build the house they want. As for tenure, they would collectively own the building, but not as with regular cooperative housing but instead with cooperative rental tenure. A good idea could be to look at German regulations of baugemeinschaft in order to make it easier to work with similar solutions in Sweden.

In planning legislation it is not possible to specifically decide about tenure and not whether a house should be a cohouse or not. But cohousing could be planned in other ways, for instance in cooperation with a housing company that wants to build a cohouse, or a baugemeinschaft for that matter. This will also require a political will among decision makers, and again, more knowledge about the benefits with cohousing is useful can be useful in order to argue for cohousing. To convert existing buildings into cohousing, it is important with timing. At certain times, the opportunity for changing a building is a lot better than usually. For instance, a lot of the housing stock built during the 1960s and 70s in Sweden will have to undergo relatively major refurbishment in a not too far away future. This could be a potential opportunity to also work with cohousing and not only upgrade and maintain technical systems. When discussing these issues, cohousing should be something to have in mind for anyone involved if environmental efficiency is a goal.

6.5 Uncertainties

There are a few uncertainties of the results, and although not as big so that they affect the overall findings, it can be good to discuss them. Food is one of the categories that probably have the biggest uncertainty in absolute terms, because food is a major causal factor of emissions of greenhouse gases, which makes even small uncertainties matter. Food consumption for residents in Färdknäppen was calculated based on order lists to the grocery company Martin & Servera and this source is good since it does not have a lot of uncertainties. This was however only half of the foodstuff used in the cohouse, and the other half of the food it is bought from the local grocery store. Since it is bought by possibly anyone in the cohouse, and receipts are not systematically saved it is hard to see what kind of foodstuff this share of all food consists of, although costs are known. Now it is assumed that the locally bought food is similar to the food ordered. Although very unlikely, if the food bought locally consisted almost entirely of beef, that would have a major impact on the final result. However, according to a resident in Färdknäppen with knowledge about the cohouse' food consumption, this is not the case[37][38]. For food consumed privately in Färdknäppen, average data was used which is a weakness, but was hard to avoid without doing a very detailed and time consuming study of each residents food habits. Another uncertainty regarding food is that it is assumed, based on what Department for Public Health Sciences & Karolinska Institutet (2009) recommends is assumed that dinners constitutes a third of everything a person eats. Since this is recommendations, and not based on actual circumstances, it is a bit uncertain how exact this assumption is.

Waste data were obtained from the waste management contractor Ragn-Sells, and are relatively certain. However, because Ragn-Sells had only been taking care of waste from Färdknäppen for two months, the only statistics they had was for April and May 2014. So although correct for these two months, there are some degree of uncertainty whether this is representative for a year, but considering the small differences between the months, it was assumed so. Household related consumption is another uncertain factor, since it not known how much residents in Färdknäppen consume privately. However, since this factor has such a small impact on the overall result, this is not a major uncertainty.

6.6 Method

The second research question asked *how well does the system analysis approach work for assessing environmental impact from a household*. Generally, the approach turned out useful. To make comparisons between behavioral- and technology-focused approaches to sustainable housing possible, the life cycle analysis-approach used in this study was useful. Sometimes, these two branches argues in different languages which makes contradicting opinions hard to compare. The system analysis-approach helps bridge this gap. System analysis enables not only these types of comparisons but comparisons without about anything that causes emissions. In order to see where

[37]Person g, resident in Färdknäppen, personal communication 26/5-14

[38] Person h, responsible for food orders in Färdknäppen, personal communication 8/4-14

efforts should be made to lower emissions, this is very useful. However, analyses of this kind requires a lot of data and knowledge about structures and organization and quickly get complex, and if data is missing or the system is presented wrong, the result will be less reliable.

The system analysis was used in a case study and Groat & Wang (2002) mean that an advantage of such a study is its possibility to find and explain causal links, but only so far as the causality is not to complex. A central part of this study was to use system analysis in a case study to assess environmental impacts from residents in a different type of housing and if so find causal links that explain the result. The study does find causal links between environmental impact and housing type to some degree, but the causal links could have been stronger with more emphasis on the human parts of the system. Several interviews were done with residents, but they were aimed at gathering facts and not subjective opinions. A good idea could have been to in a more systematic way also gather information about resident's subjective view of their way of living. This could have made the system used more complete, and thus resulted in more causality.

7 Conclusions

What can be concluded is that household-related emissions are about a ton lower for a resident in Färdknäppen compared to a person living in a corresponding average conventional home, which is in the order of 20 percent less. Food and operation of the building are the biggest sources of emissions, but the lower emissions in Färdknäppen are almost completely caused by lower energy use for heating and electricity. Heating takes less energy in Färdknäppen since floor area is smaller than average which is helped by the shared spaces in the cohouse that makes it easier to live smaller. The low electricity use can be related to both communal cooking which requires less energy per portion and less floor area per person, which is again related to the type of housing. Consumption of foodstuff is the single biggest source of emissions for a resident in Färdknäppen, but the level of emissions is almost the same as in the average alternative, since no special diet is eaten and the amount of foodstuff consumed by a person during a year is relatively fixed. Generally, for a given standard of living, and standard of a home, cohousing will be more environmentally efficient than the corresponding conventional housing. This also implies that for a fixed level of environmental impact, residents in cohouses can maintain a higher standard of living compared to residents in conventional housing.

Although a cohouse is closer to sustainable levels of greenhouse gas emissions than the conventional home in the average-alternative, it is not there yet. However, cohousing have a good potential for further savings. If more things and space are shared it would be possible to reduce individual consumption of such things which in turn saves resources. With energy use per square meter for heating being a fixed parameter in an existing building, floor area per person is what can be changed. With shared spaces, it is easier to live with less floor area which makes cohousing more adaptable to this type of change. More electricity can be saved if the share of communal meals were increased, since they require less energy, and for this too, a cohouse already has the facilities needed in the form of the communal kitchen. Emissions from foodstuff can be lowered to about half if no meat is consumed. This factor is less dependent of the type of housing, although communal cooking in a cohouse could benefit increased knowledge about different diets' environmental impact.

If combining these efforts, cohousing could be as effective as, or even more effective than homes with all the best energy saving technology available at this time, such as the "One Tonne Life"-project. Anyone involved in planning and development of housing should consider this, since it could help with a faster transition towards sustainability, without major reconstruction or substantial expenses.

As for methodology, the life cycle analysis-approach used in this study was useful to make comparisons between behavioral- and technology-focused approaches to sustainable housing possible. Sometimes, these two approaches tend to argue in different languages which make contradicting opinions hard to compare. Proponents of a technology-focused approach to sustainability tend to us a lot of "hard facts" which is less used by those arguing for a more behavior oriented approach to sustainability, and vice verse. When used to analyze a behavior-oriented approach to sustainable housing, that cohousing can be said to represent, the system analysis helps bridge this gap. System analysis enables not only comparisons of different types of housing, but comparisons with about anything that causes emissions. In order to see where efforts should be made to lower emissions, this is very useful. At the same time, analyses of this kind requires a lot of data and knowledge about structures and organization and quickly get complex, and if data is missing or the system is presented wrong, the result will be less reliable.

8 References

Antikainen, R., Lemola, R., Nousiainen, J. I., Sokka, L., Esala, M., Huhtanen, P., & Rekolainen, S. (2005). Stocks and flows of nitrogen and phosphorus in the Finnish food production and consumption system. *Agriculture, Ecosystems & Environment*, *107*(2-3), 287–305.

Avfall Sverige. (2009). *Torrkonservering av matavfall från hushåll*.

Avfall Sverige. (2013). Svensk avfallshantering 2013. *Avfall Sverige, Malmö*. Malmö. Retrieved from

Boverket. (2013). Upplåtelseformer och boendeformer i Sverige. Retrieved February 17, 2014, from http://www.boverket.se/Boende/Sa-bor-vi-i-Sverige/Upplatelseformerboendeformer/

Brunbäck, J., & Niklasson, A. (2010). *Utredning av problem vid deponigasutvinning*. Karlstads Universitet.

Carlsson-Kanyama, A. (2004). Collaborative housing and environmental efficiency: the case of food preparation and consumption. *International Journal of Sustainable Development*, *7*(4), 341.

Cordell, D., Drangert, J.-O., & White, S. (2009). The story of phosphorus: Global food security and food for thought. *Global Environmental Change*, *19*(2), 292–305.

Dahlstrøm, O. (2011). *Life Cycle Assessment of a Single- Family Residence built to Passive House Standard*. Norwegian Univeristy of Science and Technology.

Department for Public Health Sciences, & Karolinska Institutet. (2009). Matguiden: En veckodag för kvinnor - basnivå. Retrieved from http://www.folkhalsoguiden.se/upload/Mat/Broschyrer och material/Kvinnor - basniv%c3%a5.pdf

Energimyndigheten. (2010). För dig som bor i lägenhet. Retrieved May 20, 2014, from http://www.energimyndigheten.se/Hushall/For-dig-i-lagenhet/

Energimyndigheten. (2012). Vattenanvändning i hushåll. Med schabloner och mätningar i fokus. Statens energimyndighet.

Energimyndigheten. (2013). Energistatistik för flerbostadshus 2012. Eskilstuna: Statens energimynidghet.

Eon. (2013). Har du normal elförbrukning? Retrieved May 22, 2014, from http://www.eon.se/privatkund/Energieffektivisering/verktyg-och-guider/normal-elforbrukning/

Erikstam, S. (2013). *Modellering av koldioxidavtrycket för Käppalaverket med en framtida processlösning utformad för skärpta reningskrav*. Uppsala Universitet.

European Commission, Joint Research Centre, & Institute for Environment and Sustainability. (2010). *ILCD Handbook: General guide on LCA - Detailed guidance* (First edit.). Luxembourg: Publications Office of the European Union.

Familjebostäder. (2008). Bogemenskap – ett sätt att bo och leva.

Finnveden, G., & Moberg, Å. (2005). Environmental systems analysis tools – an overview. *Journal of Cleaner Production*, *13*(12), 1165–1173.

Fletcher, J. (2007). Hur man kommer igång. In E. Grip & I. Sillén (Eds.), *Gemenskap och samarbete - att bygga upp och bo i kollektivhus* (pp. 56–63). Stockholm: SABO AB.

Gilg, A., Barr, S., & Ford, N. (2005). Green consumption or sustainable lifestyles? Identifying the sustainable consumer. *Futures*, *37*(6), 481–504.

Gode, J., Byman, K., Persson, A., & Trygg, L. (2009). Miljövärdering av el ur systemperspektiv: En vägledning för hållbar utveckling. *IVL Svenska …*. IVL.

Grip, E. (2007). Storlek och utformning. In E. Grip & I. Sillén (Eds.), *Gemenskap och samarbete - att bygga upp och bo i kollektivhus* (p. 26). Stockholm: SABO AB.

Grip, E., & Sillén, I. (2007). Modeller för matlagning och matlag. In I. Sillén & E. Grip (Eds.), *Gemenskap och samarbete - att bygga upp och bo i kollektivhus*. Stockholm: SABO AB.

Groat, L., & Wang, D. (2002). *Architectural Research Methods*. Wiley.

Helander, J. (2013). *Kollektivboende: En analys av boendeformens struktur i relation till hållbar utveckling*. Uppsala Universitet.

Jarvis, H., & Fransson, B. (2010). Shared Meals - the Hub of Living Together. In D. U. Vestbro (Ed.), *Living together - Cohousing Ideas and Realities Around the World* (pp. 178–183). Stockholm: Division of Urban and Regional Studies, Royal Institute of Technology.

Jordbruksverket. (2013). Livsmedelskonsumtion och näringsinnehåll. SCB.

Kollektivhus NU. (2014). Kollektivhus NU. Retrieved February 24, 2014, from http://kollektivhus.nu/index.html

Kollektivhuset Södra Station. (n.d.). Om oss. Retrieved May 22, 2014, from http://sodrastation.org/om-oss

Kollektivhusföreningen Cigarrlådan. (n.d.). Aktiviteter. Retrieved April 11, 2014, from http://www.cigarrladan.org/aktiviteter

Kollektivhusföreningen Färdknäppen. (2013). *Färdknäppen 2012: Verksamhetsberättelse*.

Kollektivhusföreningen Färdknäppen. (2014). *Färdknäppen 20 år! Verksamhetsberättelse 2013*.

Kvale, S., & Brinkmann, S. (2009). *Den kvalitativa forskningsintervjun* (2:a upplag.). Lund.

Kärnekull, K., & Blomberg, I. (2013). *Bygga seniroboende tillsammans. En handbok* (p. 132). Svensk Byggtjänst.

Livsmedelsverket. (2012). Riksmaten - vuxna 2010-11: Livsmedels- och näringsintag bland vuxna i Sverige. Uppsala.

Livsmedelsverket. (2014a). Livsmedelsdatabasen. Retrieved May 23, 2014, from http://www7.slv.se/Naringssok/

Livsmedelsverket. (2014b). Vegetarisk mat. Retrieved July 03, 2014, from http://www.slv.se/sv/grupp1/Mat-och-naring/kostrad/Rad-om-vegetarisk-mat/

Melvær, M. S. (2012). *Life-cycle assessment of a multi-family residence built to passive house standard*. Norwegian University of Science and Technology.

Miljödepartementet. (2008). Förbud mot fosfater i tvättmedel. Retrieved May 23, 2014, from http://www.regeringen.se/sb/d/10349/a/99552

Miljödepartementet. (2010). Förbud mot fosfater i diskmedel. Retrieved May 23, 2014, from http://www.regeringen.se/sb/d/12858/a/143110

Myrdal, A. (1935). Kooperativa och kollektiva bostadsformer i Sverige. Retrieved from http://www.stockholmskallan.se/Soksida/Post/?nid=28430

Näsström, G. (1935). Hem i kollektivhus: Catalogue from Svenska Slöjdföreningens exhibition. Retrieved from http://www.stockholmskallan.se/Soksida/Post/?nid=28390

One Tonne Life. (2011). One Tonne Life Slutrapport. Retrieved from http://www.onetonnelife.se/wp-content/uploads/2011/07/OTL_slutrapport_low1.pdf

Palm, J.-O., & Sundqvist, D. (2010). *Miljöpåverkan från avfall*.

Palm Lindén, K. (1992). *Community and Privacy in the Swedish Collective House*. Lund.

Persson, T. (2008). Koldioxidvärdering av energianvändning: Vad kan du göra för klimatet? Eskilstuna: Energimyndigheten.

Räty, R., & Carlsson-Kanyama, A. (2007). *Energi- och koldioxidintensiteter för 319 varor och tjänster*. Stockholm.

Röös, E. (2012). *Mat-klimat-listan version 1.0*. Uppsala.

Sandström, Y., & Gray, M. (2010). Suitable Forms of Ownership/Tenure and Economic Aspects of Cohousing. In D. U. Vestbro (Ed.), *Living together - Cohousing Ideas and Realities Around the World* (pp. 164–169). Stockholm.

Sangregorio, I.-L. (2010). Collaborative Housing from a Women's Perspective. In D. U. Vestbro (Ed.), *Living together - Cohousing Ideas and Realities Around the World* (pp. 114–123). Stockholm: Division of Urban and Regional Studies, Royal Institute of Technology.

Sanne, C. (2012). *Hur vi kan leva hållbart 2030*.

SCB. (2008). Boende och boendeutgifter 2006.

SCB. (2010). *Hushållens utgifter 2007-2009*.

SCB. (2012). *Bostads- och byggnadsstatistisk årsbok 2012*.

Sismondo, S. (2010). *An Introduction to Science and Technology Studies* (Second edi.).

Stockholms Stad. (2014). Avfallstaxa 2014, *1*(21), 1–21. Retrieved from http://www.stockholm.se/-/Nyheter/Bygga--Bo/Ny-avfallstaxa1/

Svane, Ö. (2009). ...But most buidlings are already there: Basic starting points for environmental management in the housing sector. In E. P. Hammond & A. D. Noyes (Eds.), *Housing: Socioeconomic, Availability & Development Issues* (pp. 149–159).

Trafikkontoret Stockholms Stad. (2011). Plockanalys kärl- och säckavfall 2011.

Uppsalahem. (2011). Kollektivhuset Blenda. Retrieved from http://www.uppsalahem.se/Kundservice/A-O/Kollektivhuset-Blenda/

Wallén, E. (1999). Livscykelanalys av dricksvatten - en studie av ett vattenverk i Göteborg.

Wangel, J. (2013). Hur hållbara är Hammarby sjöstad och Norra Djurgårdstaden? In H. Teleman, C. Caldenby, E. Ullstad, & F. von Platen (Eds.), *Hållbarhetens villkor*. Malmö, Sweden: Arena.

Weidema, B. P., & Wesnaes, M. S. (1996). Data quality management for life cycle inventories - an example of using data quality indicators. *Journal of Cleaner Production*, *4*(3), 167–174.

Vestbro, D. U. (2009, February). Pristak - en garanti för EKBO/Gebers överlevnad? *Bo Tillsammans*, 3–4.

Vestbro, D. U. (2010a). Concepts and terminology. In D. U. Vestbro (Ed.), *Living together - Cohousing Ideas and Realities Around the World* (pp. 21–29). Stockholm: Divison of Urban and Regional Studies, Royal Institute of Technology.

Vestbro, D. U. (2010b). History of Cohousing - Internationally and in Sweden. In D. U. Vestbro (Ed.), *Living together - Cohousing Ideas and Realities Around the World* (pp. 42–55). Division of Urban and Regional Studies, Royal Institute of Technology.

Vestbro, D. U. (2012). Saving by Sharing – Collective Housing for Sustainable Lifestyles in the Swedish Context. In *Paper for the 3rd International Conference on Degrowth for Ecological Sustainability and Social Equity, Venice, 19th – 23rd September 2012* (pp. 1–13).

William-Olsson, M. (1994). *Färdknäppen: Ett kollektivhus för andra halvan av livet*. Stockholm: SABO Utveckling.

William-Olsson, M. (2007). Färdknäppen: Basvaror från grossist. In E. Grip & I. Sillén (Eds.), *Gemenskap och samarbete - att bygga upp och bo i kollektivhus* (pp. 43–44). Stockholm: SABO AB.

William-Olsson, M. (2014). Om oss. *2014*. Retrieved from http://www.fardknappen.se/fardknappen.se/Om_oss.html

Wyly, E. (2011). Positively Radical. *International Journal of Urban and Regional Research*, *35*(September), 889–912.

Xue, X., & Landis, A. E. (2010). Eutrophication potential of food consumption patterns. *Environmental Science & Technology*, *44*(16), 6450–6456.

9 Appendix: Data synthesis and quality assessment

9.1 Assessment criteria

	1	2	3
Reliability	Data verified or partly verified by multiple sources or similar.	Data partly based on assumptions or estimates by experts	Data based on assumptions
Temporal correlation	Data less than 3 years old	Data less than 6 years old	Data older than 6 years
Geographical correlation	Data from the area of study or average data from a larger area were the study object is located	Data from area with similar characteristics	Data from an unknown area or area with different characteristics

Based on (Weidema & Wesnaes, 1996)

9.2 General LCI-data

9.2.1 Emissions from operation

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Water	kg CO_2e /m3	0,1214	Wallen (1999)	Value for Gothenburg	2	3	2
Sewage	kg CO_2e /m3	0,2218	Erikstam (2013)	Value for Käppalaverket	2	1	2
Heating	kg CO_2e /Wh	0,000055	Persson (2008)		1	2	2
Electricity	kg CO_2e /Wh	0,0004	Gode, Byman, Persson, & Trygg (2009)	Value for Nordic electricity mix	1	2	2

9.2.2 Emissions from waste management

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Newsprint	kg CO_2e /kg fraction	0,17	Palm & Sundqvist (2010)	Including upstream emissions	1	2	2
Cardboard		0,17					
Metal		1,15					
Plastic		3,43					
Glass		0,51					
Organic waste		4,15					
Household garbage		2,95					
Bulky waste		2,95					

9.2.3 Emissions from other household-related consumption

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Furniture, inventories, carpets and textiles	kg CO_2e /SEK	0,026	Räty & Carlsson-kanyama (2007)	Furniture	2	2	2
Household equipment (clothing iron, dishware, tools etc.)		0,037		Fridge and freezer			
Radio and TV		0,025		TV			
Books, magazines and television license (including newspapers)		0,016		Books			

9.2.4 Emissions from foodstuff

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Flour	kg CO_2e /kg foodstuff	0,8	Röös (2012)		2	1	2
Pasta		0,8					
Cereals		0,6					
Bread and cookies		0,8					
Sugar		0,6					
Rice		2,0					
Beef		26,0					
Pork		6,0					
Chicken		3,0					
Game		0,5					
Charcuterie		7,0					
Prepackaged food with meat		2,0					
Fish		3,0					
Milk and yoghurt		1,0					
Cream		4,0					
Cheese		8,0					
Butter		8,0					
Oil		1,5					
Root vegetables		0,2					
Fresh vegetables		0,6					
Cabbage and onion		0,2					
Pickled vegetables		0,2					
Fruit		0,6					
Nuts		1,5					
Juice and jam		3,0					
Potato		0,1					
Coffee		3,0					
Tea		3,0					
Soda		0,3					
Beer		0,4					
Wine		1,9					
Spirits		2,3					
Crisps		2,0					
Spices		1,0					
Ice-cream		2,0					
Sauce		1,0					
Candy		2,0					

9.3 Specific LCI-data for the average alternative

9.3.1 Operation

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Water	m3/person and year	73	Energimyndigheten (2012)	Value for Gothenburg	1	1	2
Sewage	m3/person and year	73	-	Assumed to be the same as incoming water	3	1	2
Heating	Wh/person and year	146000	Energimyndigheten (2013)		1	1	2
Electricity	Wh/person and year	40000	Energimyndigheten (2010)	Value for Nordic electricity mix	1	2	2
Floor Area	m2/person	67	SCB (2008)		1	2	2

9.3.2 Waste

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Newsprint	kg/person and year	37,5	Avfall Sverige (2013)		1	1	2
Cardboard		13,1	Avfall Sverige (2013)		1	1	2
Metal		1,6	Avfall Sverige (2013)		1	1	2
Plastic		5,2	Avfall Sverige (2013)		1	1	2
Glass		19,2	Avfall Sverige (2013)		1	1	2
Organic waste		70,4	Avfall Sverige (2013)		1	1	2
Household garbage		187,8	Trafikkontoret Stockholms Stad (2011)		1	1	1
Bulky waste		49,2	Avfall Sverige (2013)		1	1	2

9.3.3 Household-related consumption

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Furniture, inventories, carpets and textiles	SEK/person and year	4050	SCB (2010)	Furniture	1	2	2
Household equipment (clothing iron, dishware, tools etc.)		0,037		Fridge and freezer			
Radio and TV		0,025		TV			
Books, magazines and television license (including newspapers)		0,016		Books			

9.3.4 Consumption of foodstuff

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Flour	kg/person and year	13,5	Jordbruksverket (2013)		1	1	2
Pasta		8,7					
Cereals		4,2					
Bread and cookies		71,7					
Sugar		6,8					
Rice		5,1					
Beef		12,2					
Pork		15,8					
Chicken		17,5					
Game		2					
Charcuterie		21,7					
Prepackaged food with meat		9,7					
Fish		20,8					
Milk and yoghurt		119,6					
Cream		11					
Cheese		18,4					
Butter		14,6					
Oil		1,5					
Root vegetables		19,3					
Fresh vegetables		33,6					
Cabbage and onion		13,9					
Pickled vegetables		15					
Fruit		70,5					
Nuts		2,9					
Juice and jam		27,9					
Potato		55,1					
Coffee		8,4					
Tea		0,3					
Soda		94,7					
Beer		49,7					
Wine		24,3					
Spirits		2,5					
Crisps		1,9					
Spices		1,7					
Ice-cream		9,5					
Sauce		14,4					
Candy		17,3					

9.4 Specific LCI-data for Färdknäppen

9.4.1 Operation

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Water	m3/person and year	55	Economist at Familjebostäder, personal communication 23/4-2014		1	1	1
Sewage	m3/person and year	55	-	Assumed to be the same as incoming water	3	1	1
Heating	Wh/person and year	149400	Economist at Familjebostäder, personal communication 23/4-2014		1	1	1
Electricity	Wh/person and year	24844	Kollektivhusföreningen Färdknäppen (2014), personal communication with 10 households in Färdknäppen		2	1	1
Floor Area	m2/person	50	Economist at Familjebostäder, personal communication 23/4-2014		1	1	1

9.4.2 Waste

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Newsprint	kg/person and year	37,5	Manager at Ragn-Sells, personal communication 19/6-2014		1	1	1
Cardboard		13,1	Manager at Ragn-Sells, personal communication 19/6-2015		1	1	1
Metal		1,6	Manager at Ragn-Sells, personal communication 19/6-2016		1	1	1
Plastic		5,2	Manager at Ragn-Sells, personal communication 19/6-2017		1	1	1
Glass		19,2	Manager at Ragn-Sells, personal communication 19/6-2018		1	1	1
Organic waste		70,4	Economist at Familjebostäder, personal communication 23/4-2014		1	1	1
Household garbage		187,8	Person responsible for cohousing at Familjebostäder, personal communication 5/6-2014	Calculation based on costs for landlord	2	1	1
Bulky waste		49,2	Manager at Ragn-Sells, personal communication 19/6-2014		1	1	1

9.4.3 Household-related consumption

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Furniture, inventories, carpets and textiles	SEK/person and year	4050	SCB (2010)	Furniture	1	2	2
Household equipment (clothing iron, dishware, tools etc.)		0,037		Fridge and freezer			
Radio and TV		0,025		TV			
Books, magazines and television license (including newspapers)		0,016		Books			

9.5

9.5.1 Consumption of foodstuff

Category	Unit	Amount	Source	Comment	Reliability	Temporal correlation	Geographical correlation
Flour	kg/person and year	17,7	Person responsible for food orders in Färdknäppen (personal communication 8/4-14), the accountant at Färdknäppen (personal communication 26/5-14) & Jordbruksverket (2013)	Calculations of complete food consumption based on communal dinners in Färdknäppen and national average consumption for the rest	2	1	2
Pasta		8,8					
Cereals		3,6					
Bread and cookies		64,7					
Sugar		8,2					
Rice		7,2					
Beef		13,9					
Pork		13,5					
Chicken		16,0					
Game		2,1					
Charcuterie		18,5					
Prepackaged food with meat		8,3					
Fish		28,4					
Milk and yoghurt		102,0					
Cream		9,4					
Cheese		18,1					
Butter		16,2					
Oil		3,8					
Root vegetables		25,9					
Fresh vegetables		32,4					
Cabbage and onion		18,5					
Pickled vegetables		20,1					
Fruit		60,6					
Nuts		2,5					
Juice and jam		24,7					
Potato		84,8					
Coffee		10,4					
Tea		0,3					
Soda		80,8					
Beer		42,4					
Wine		20,9					
Spirits		2,1					
Crisps		1,6					
Spices		3,2					
Ice-cream		8,1					
Sauce		12,6					
Candy		14,8					