CHALMERS
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Development and Evaluation of a Carbon Label for Meals at a University Restaurant

Master's thesis in Industrial Ecology

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Department of Energy and Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2016

MASTER'S THESIS 2016

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ABSTRACT

Food related GHG emissions will most likely need to be reduced in order to reach internationally agreed climate targets. One of the measures under debate is carbon labeling of food products. Consumer reactions to such labels, however, are not yet well researched. A carbon label was therefore developed and tested in a real life experiment at a university restaurant. Data on the visitors´ consumption was collected on the level of the individual, during six weeks before and after label introduction. Consumption behavior of groups of different gender, age, dietary habit and frequency of visit was traced over time. However, factors other than product footprint information, in particular taste preferences, were found to dominate food choices. On average a reduction in emissions per serving by two percent was observed. However, a high standard deviation of 12% implies high uncertainties to the collected data, not allowing to draw definite conclusions on whether the label had an effect or not.

Keywords: Carbon footprint, carbon food label, consumer behavior, sustainable food consumption

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1 INTRODUCTION

1.1 Background

When it comes to climate change mitigation, the transition of the energy sector from fossil fuel use to renewable sources, has long received most attention and was perceived as key solution to the climate challenge. More recently it has been emphasized (Gerber, P.J. et al. , 2013; Bryngelsson, et al. 2016) that, depending on the climate sensitivity, cuts in greenhouse gas (GHG) emissions from energy generation will most likely not be sufficient in order to limit global average temperature increase to below 2°C compared to pre-industrial levels, as agreed by 195 nations at the UNFCCC Climate Conference in Paris in December 2015 (European Commission, 2016). Around 35% of worldwide anthropogenic GHG emissions stem from the energy sector. The agriculture, forestry and land-use sector is currently responsible for about another quarter of emissions (IPCC, 2014). This sector is characterized by its intensity in methane (CH_4) and nitrous oxide (N_2O) emissions, which are 34 and 298 times more potent greenhouse gasses than carbon dioxide (CO_2) respectively (IPCC, 2013). Apart from that, global food systems cause multiple other environmental problems from local to global scale, such as deforestation, soil erosion, disruption of nutrient cycles or the loss of habitat, biodiversity and other ecosystem services. Equally substantial are closely related social issues such as food security, hunger, malnutrition and poverty. Moreover, it has to be considered that global food and agricultural systems will face a significant rise in demand during the next decades, driven by a growing world population, that is expected to reach 9,7 billion people by 2050 (United Nations, Department of Economic and Social Affairs, 2015), as well as increasing wealth and economic development in emerging regions (Gerber et al., 2013). In today´s most developed countries, such as Sweden, as much as 25% of the annual emissions caused by a single citizen´s private consumption are related to food (Swedish Environmental Protection Agency, 2010). Given the global strive for western living standards and current food production practices, is obvious that the reduction of food related emissions has a crucial role to play in climate change mitigation.

Multiple options pose such mitigation potential in the food and agricultural sector. At the supply side agricultural efficiency and productivity can be increased (Bryngelsson et al., 2016). The gap in emission intensities between lowest and highest emitting production units of the same product is large and thus poses considerable potential for improvement. Secondly, widespread implementation of advanced technologies, for example in manure management, provide further improvement opportunities on the supply side. Changes on the demand side allow to tap the potential lying in the emission disparity between different types of products. This requires changes towards low carbon diets, away from livestock products, particularly from beef and dairy products, substituted with plant based products. In addition, despite expected global demand growth, there is potential to cut per capita demand by reducing food waste. Bryngelsson et al. (2016) point out that only in combination the above measures are likely to reach the required emission targets.

Less clear remains, under which governance structures the identified measures are implemented most effectively. Governmental or, even better, inter-governmental efforts such as comprehensive carbon taxing to account for environmental externalities of food products or cap & trade schemes could be effective. Regarding consumption taxes on food, however, knowledge about their potential, as well as their economic and social cost is still limited (Wirsenius et al. 2011; Säll and Gren, 2015; Bryngelsson et al., 2016). The political philosopher Michael Sandel also points out a moral flaw to it: "... money [...] dissolves the very thing we are aiming at." (Sandel, 2012) In other words, putting a price on nature would diminishes its intrinsic value. Similarly, for the agricultural sector to become included in carbon trading schemes is said unlikely to happen (Vlaeminck, et al. 2014). Voluntary initiatives from private actors are suggested to play an important role in filling the gap of slow progressing public endeavors (Vlaeminck, et al. 2014). Given the immense number of involved actors, who play different roles and are connected through a network of global interactions, the food system occurs to be of high complexity. Taking food supply chains as a simplified model of the complex system (see Figure 1), different actor groups, from producers at the farm level up to end consumers and waste management authorities, can be identified. Taking a holistic systems-perspective, the question is, which actors at which stage have the power and capacity to influence the whole system?

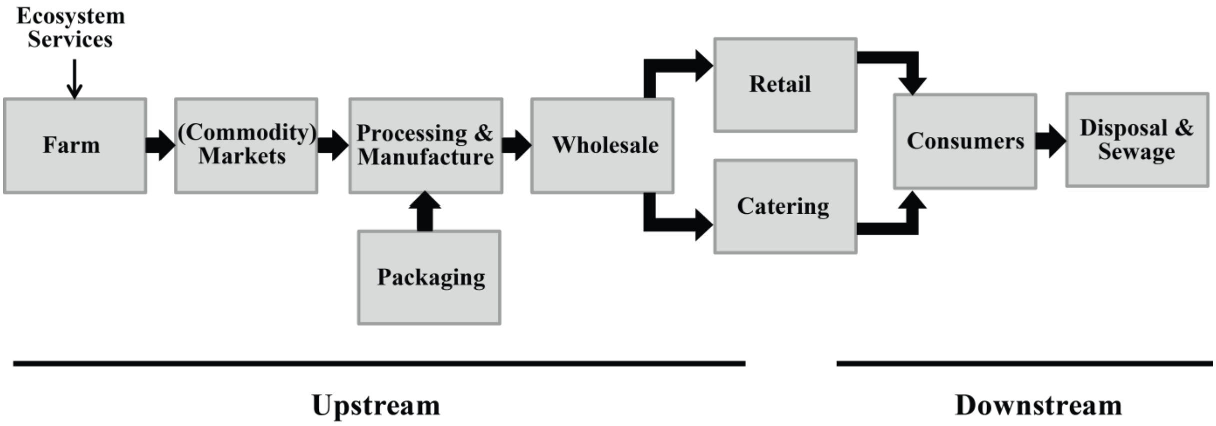

Figure 1: Simplified model of a food supply chain.

In answer to this question it appears that retailers, restaurants and caterers take a crucial position. On the retail side, global grocery chains (Chkanikova et al., 2013; OECD, 2014) as well as global and local players in the restaurant business, are acting at the interface of buying power and selling power. On the one hand, they are situated at the last stage of all upstream activities. Hence their decisions on assortment and sourcing have an influence on all earlier chain stages. On the other hand, they represent the only actor group which is directly interacting with the end-consumers. This makes them an influential channel to steer short-term food choices and potentially long-term dietary habits.

Regarding the latter, environmental labeling is one of the measures, which was proposed by the United Nations Environment Program (UNEP) to achieve the sustainable development goals in Agenda 21, in the Rio de Janeiro summit in 1992. It is thought as a contribution to sustainable consumption patterns by enabling consumers to become more aware and make informed choices (UNEP, 1992). Yet other researchers and policy-makers argue for so called 'consumer-silent' strategies, because the heterogeneous and unpredictable behavior of consumers would not qualify them as change agents (Spaargaren et al., 2013). Nonetheless experiences from a number of labeling programs around the world, such as energy-efficiency labels on white goods, electronics or motor vehicles, organic and fair trade labeled grocery food items as well as consumer surveys suggest that environmental labels have the potential to simulate sustainable consumption (Shewmake et al., 2015). When it comes to the potential of low carbon diets, existing research has mostly been modeling hypothetical changes in consumption, largely disregarding practical restrictions such as consumer preferences for health, taste, other sensory qualities and price as well as the challenge of breaking long-term habitual practices (Bryngelsson et al., 2016). To date there is little empiric evidence on the effectiveness of carbon labels to change food choices. In particular lacking are results with high enough data resolution to trace behavior of single individuals over time, rather than analyzing changes in product shares on an aggregate level (e.g.: Vanclay et al., 2011; Matsdotter et al., 2014; Vlaeminck, et al., 2014; Spaargaren et al., 2013; Hainmueller et al., 2014).

Moreover, previous studies have mostly been focusing on product labeling in the context of grocery shopping, where typically the choice is between labeled and non-labeled products of the same product category. It has been criticized however, that often emission discrepancies among competing products of the same product group are minor and will hence not make much of a difference on an aggregate level (Shewmake et al., 2015). This limitation may be overcome by elevating carbon labeling from the level of single products to entire meals. Doing so, footprints are communicated more selectively where products actually have substantial differences in emissions (Upham and Bleda, 2009). Another problem with labeling single products is that the required life cycle assessments (LCAs) are often not cost effective (Shewmake et al., 2015), while footprints of meals can be calculated, based on existing LCA data. This makes an interesting case for the application of carbon labeling in a restaurant setting. However, as pointed out by Röös and Tjärnemo (2011), questions on the optimal design and information content of carbon food labels need further investigation.

1.2 Aim of study

The aim of this study is to develop and test a carbon labeling scheme for restaurants applied in a field experiment, which will allow to analyze the effect and hence to elucidate potential hurdles and prerequisites for the implementation of such schemes. This shall eventually allow for the label to be copied to other restaurants.

Data on consumer behavior shall be collected on the level of the individual, which allows to investigate correlations between behavioral change and certain characteristics, such as age, gender and dietary habit. To my best knowledge, this is unique to research performed up until now, making this study a valuable contribution to the current research agenda.

This study aims to answer the following research questions:

- How should a carbon label for meals in a restaurant look like in order to communicate the climate impact in an effective but yet simple way?
- How can a carbon footprint label be implemented to existing structures of a restaurant´s daily operations in an efficient way?
- How does the introduction of such a label to a university canteen setting affect consumer behavior?

1.3 Structure of the report

In the following chapters of this report I will first explain which methods I used to perform my research. This is followed by a literature review in two parts. The first part is dealing with the concept of carbon footprints and its application in the food sector. The second part of the literature review gives an overview of food product labels, particularly focusing on previous experiences and research regarding carbon labels. Based on existing knowledge I present criteria for the label design, my label drafts and the final design in chapter 5. Results regarding the effect of the label on consumer behavior are presented in chapter 6. This is followed by a discussion of the findings as well as limitations to my research, before conclusions are drawn in the final chapter.

2 METHOD

2.1 Experimental Set Up

In order to answer the defined research questions, a carbon label was introduced to the menus of a restaurant in a natural field experiment. Such an experiment has been defined by List (2006) as that the study subjects naturally undertake their actions in their usual environment, not knowing about their participation in a study. To date only few experiments have been done to investigate consumer response to carbon labeling. Vlaeminck et al. (2014) studied reactions in a framed field experiment, where they artificially reconstructed a super-market environment and explicitly asked consumers to participate. This approach, however, is limited in that the framed environment in itself potentially influences behavior (List, 2006). The advantage of a natural field (i.e. real world) experiment - as conducted previously also by Vanclay et al. (2011) and Spaargaren et al. (2013) - is the combination of randomization and realism, the most desirable feature of each, laboratory and naturally-occurring data (List, 2006).

To come up with the design specifications of the experiment, I reviewed literature on experimental design in general (List, 2006; Levitt and List, 2009; List, 2011; List et al., 2011) and in the specific context of environmental product labeling (Vanclay et al., 2011; Spaargaren et al., 2013; Hainmueller et al., 2014; Matsdotter et al., 2014; Vlaeminck et al., 2014). Recommendations from literature in combination with the given conditions in the field result in the following set-up:

The experiment was conducted at *Kårrestaurangen* (Student Union Restaurant), at Chalmers University of Technology´s Johanneberg Campus in Gothenburg, Sweden. The chosen restaurant is only one of many options for students and staff to have lunch around campus. It serves between 400 and 600 lunches per day all weekdays, with the largest part of the customers being bachelor and master students in engineering and natural sciences, and to a smaller extent also PhD students, researchers and staff. Consumption behavior could be documented only of customers with an electronic prepay card registered via the student union system, i.e. only students were observed.

The university´s academic calendar determines sales levels and opening periods of the respective restaurant. Timing and maximal length of the experimental phases were therefore restricted by desirably stable sales levels and a continuous customer base throughout the experiment. For this reason a *reference-phase* (before introduction of the carbon label) was set to six consecutive weeks and a *label-phase* (after implementation) to seven consecutive weeks, Mondays to Fridays (of which the restaurant was closed two days in each phase) between February and May 2016.

In order to avoid confusing the effect of the carbon label with unobserved market effects, other conditions such as product prices were kept equal throughout the experiment. Additionally, I used a second sales point with similar sales volumes, operated by the same company in the same building and with partly overlapping customers as control group. This shall allows me to control for potential time-varying effects in consumer preferences, for example due to media coverage of nutrition related topics. Much harder, if not impossible, to control for within the given scope of this study are the many other factors playing into the purchase decision of a canteen lunch. Aspects such as taste, other sensory qualities, product similarity and substitution dynamics between different dishes were previously found to play a bigger role in people´s decision making than environmental features (Röös and Tjärnemo, 2011; Grunert et al., 2014). Kårrestaurangen offers seven (with some exceptions of eight) dishes every day. Three of these, the *Classic vegetarian*, *Classic Fish* and *Classic Meat*, change daily; the other four, which is a vegetarian salad, a fish salad, a meat salad and a soup, change weekly. The offered dishes during the reference and the labeling phase were not identical. In this aspect the conducted study differs from previous ones, in which the exact same products were offered before and after the introduction of a label. On the one hand, this authentically depicts a real world decision context, while on the other hand possible influence on results is not clear in advance.

With the beginning of the label-phase I provided visitors with information in various formats. Firstly, there was the label itslef, displaying the carbon footprint for every dish on the menu. Secondly, I gave additional information in Swedish and English to help guests understand the label and its background as well as to answer expectedly araising questions. This was presented in four different formats: The print menu displayed the label scale below the daily choices, indicating the footprint of the average swedish meal as a refernce point (see Figure 11); Posters by the restaurant´s entrance, visible to guests before purchase, provided background information on the relationship between food and climate change, on the role of the consumer and on how the numerical footprint values are to be interpreted in perspective (see Appendix Figure 1

Appendix Figure 2Appendix Figure 4); A QR-code on the posters and the menus directed people to the restaurant´s webpage, where this information was given in more detail, including the technical ins and outs of the calculations behind the label; Moreover, during the first two weeks of the label-phase, small stands on the lunch-tables provided concise information in flyer format (see Appendix Figure 5Appendix Figure 6).

Guests did not know about the motivation and ongoing study behind the label until after the end of the experiment. Moreover, I refrained from taking measures beyond information provision, as done by Spaargaren et al. (2013). Cross-effects from measures, such as feedback in the form of individual or collective emission scores, would not allow to isolate the effect of the label, which was the focal point of this study. They are likely though, to increase the label´s effect and should therefore be considered for follow up projects.

2.2 Footprint calculations

2.2.1 Footprint data used in this study

I calculated the footprints based on footprint data for different categories of ingredients which were available from previous research. The work by Bryngelsson and colleagues (2016) served as the main source of footprint data. Where necessary, I complemented it with data from other sources.

Bryngelsson et al. (2016) reviewed different LCA studies on food products and harmonized them in such a way that system boundaries are applicable to the current Swedish context. This source hence provides the most up-to-date information that is available for the specific regional context of the carbon label. I also adopted the aggregation level in which the ingredients were grouped from the same source. This means the underlying footprint data did not distinguish between every distinct ingredient, but rather between categories of similar products and similar emissions. On the one hand this allows straightforward approximations of the footprints of multiple-ingredient dishes, while on the other hand still keeping enough detail to be reliable. For example, it was not distinguished between potatoes and carrots, but both were covered by the category of root vegetables. An overview of the 34 categories is given in Table 1.

Beyond these initial categories, I decided to disaggregate the product category of beef further into four regions, which the restaurant is procuring from: Western Europe, Eastern Europe, North America and South America. For this purpose I used data from a publication of the Food and Agriculture Organization of the United Nations (FAO) by Opio et al. (2013).

For fish and seafood only very little emission data is available. It therefore seemed to be the best available approximation to use data on Norwegian produce from Winther et al. (2009) and adjust system boundaries to wholesale-level in Gothenburg. The resulting emission values can be seen in Table 1.

Furthermore, an additional category had to be added for plant-based meat replacements such as tofu, which the restaurant uses regularly. From a LCA study by Head et al. (2011) I generated an average emission value for the different types of meat replacements (see Table 1).

Arguably the high aggregation of fruit, distinguishing only between domestic and imported items, does not depict the large difference between ship and flight cargo emissions accurately. However, fruit is rarely used in Kårrestaurangen´s kitchen and if so, only in minor amounts. The available data were therefore considered sufficient.

A higher resolution would indeed be desirable, though, for different beef cuts and dairy products. These have relatively high emissions, making calculated footprints hence very sensitive to more aggregated, less accurate input data. For the scope of this study, however, I decided not to go into more depth.

Minor ingredients, making up less than about five grams in mass, such as spices and seasoning, were disregarded, as their influence on the overall footprint can be assumed negligible.

To calculate the footprint of each meal, the mass of ingredients in each product category had to be known. The restaurant´s kitchen staff, however, is not following formally written recipes in their daily operations. The composition of the meals thus exists only as the staffs´ knowledge. The executive head chef therefore recorded the amount of ingredients per product category to his best knowledge, broken down to a per-serving level. The overall weight per serving was introduced as a control variable and I continuously checked samples of the recorded amounts for their plausibility.

2.2.2 Extended System Boundaries: Farm to Fork

Another aspect, which may be viewed critically about the underlying footprint data, is that their system boundaries are not entirely harmonious. For some products they comprise life cycle stages up to farm gate and for others to processing and packaging only. Distribution and preparation of the food is not accounted for. Only little information was available about these later stages and they could be expected to make minor contributions. For this reason I decided to neglect them for the experiment. Nonetheless, I attempted to estimate what the approximate farm to fork emissions for each food category would have been. Based on work by Sjörs et al. (2016) the applied system boundaries of each category could be identified, harmonized and extended with average emission values for distribution, packaging (both from source Ahlm and Persson, 2002) and unavoidable food waste (from source Livsmedelsverket, 2015). The resulting emission values with extended system boundaries are presented in Table 1 for each category.

It can be seen that for most categories there is no or only a marginal difference. For few, however, emissions are up to 55 % higher with extended boundaries. This is due to packaging and distribution emissions in the case of bread as well as distribution and unavoidable waste in the case of vegetables.

Emissions from the kitchen´s energy use for meal preparation, however are still not included in these numbers, as this could only roughly be estimated on a per meals level. A study by Mudie et al. (2013), found an average daily electricity use among fourteen commercial kitchens in the UK to be about 300 kWh. The figure is said to be only marginally affected by trade volumes. Multiplying this with the emission intensity of the Swedish electricity mix, of about 23 g CO_2-eq/kWh (Brander et al., 2011), and distributing the emissions over about 1000 meals per day, it results approximately 7 additional grams of CO_2-eq per meal. This is a marginal difference and may therefore be neglected.

Product Category	Specification	footprint in kg CO2-eq/kg product (as used for the label)	Footprint including packaging, distribution and unavoidable waste in kg CO2-eq/kg product	Source
Meat				
Beef *	North America	49.27		Opio et al., 2013
	Latin America & Caribbean	132.78		Opio et al., 2013
	Western Europe	43.36	43.61	Bryngelsson et al., 2016
	Eastern Europe	40.72		Opio et al., 2013
Mutton		38.39	38.64	Bryngelsson et al., 2016
Pork		6.05	6.30	Bryngelsson et al., 2016
Poultry		2.41	2.45	Bryngelsson et al., 2016
Fish				
Salmon (Farmed)		3.28	3.28	Winther et al., 2009
Blue Mussels (Farmed)		1.54	1.54	Winther et al., 2009
other Fish&Sea Food (Farmed)		3.28	3.28	assumption: same as for salmon
Cod (Wild)		2.47	2.47	Winther et al., 2009
Saithe (Wild)		2.62	2.62	Winther et al., 2009
Haddock (Wild)		3.76	3.76	Winther et al., 2009
Herring (Wild)		0.77	0.77	Winther et al., 2009
Mackerel (Wild)		0.80	0.80	Winther et al., 2009
other Fish&Sea Food (Wild)		3.03	3.03	Bryngelsson et al., 2016
Vegetable Proteins				

Legumes	All types of beans, lentils and peas	0.54	0.57	Bryngelsson et al., 2016
Seeds & Nuts	All types of nuts and seeds such as sun flour, pumpkin, chia, flax seeds, sesame	1.19	1.36	Bryngelsson et al., 2016
Soy Milk		0.25	0.25	Bryngelsson et al., 2016
Meat Alternatives	Tofu, Quorn, Valess, Groentenschijf, Falafel etc.	3.00	3.00	Head, Sevenster and Croezen, 2011
Egg		0.97	1.12	Bryngelsson et al., 2016
Dairy **				
Liquid Dairy	Milk, cream, sour cream, yoghurt, crème fraîche, etc.	1.24	1.25	Bryngelsson et al., 2016
Cheese		10.76	10.78	Bryngelsson et al., 2016
Butter		10.87	10.89	Bryngelsson et al., 2016
Vegetable Oils		2.15	2.17	Bryngelsson et al., 2016
Grains				
Rice		1.75	1.75	Bryngelsson et al., 2016
Bread		0.44	0.44	Bryngelsson et al., 2016
Pasta		0.57	0.57	Bryngelsson et al., 2016
Other grains	All kind of grains other than rice, including maize, amaranth, quinoa, bulgur etc.	0.30	0.47	Bryngelsson et al., 2016
Flour	all types	0.30	0.47	Bryngelsson et al., 2016
Vegetables				
Cabbage, Onions etc.	All kind of cabbage & onion-like vegetables which are grown above ground and can be sourced locally in Swedish latitudes: Cabbage, kale onions, leek, cauliflower, broccoli, pumpkin etc.	0.23	0.32	Bryngelsson et al., 2016
Potatoes & Roots	All kind of root vegetables: potatoes, carrots, parsnip, turnip cabbage, celeriac, beetroot, radish, daikon, ginger, etc.	0.14	0.22	Bryngelsson et al., 2016

Green Vegetables	Remaining vegetables which do not belong to the other two categories: Salad-like vegetables, tomatoes, cucumber, zucchini, eggplant, asparagus etc.; also mushrooms	0.70	0.92	Bryngelsson et al., 2016; Gunady, Biswas, Solah and James, 2012
Sugar		4.02	4.02	Bryngelsson et al., 2016
Fruit				
Fruit imported	includes coconut milk	0.92	0.98	Bryngelsson et al., 2016
Fruit domestic		0.20	0.22	Bryngelsson et al., 2016
Alcohol		1.73	1.73	Bryngelsson et al., 2016

Table 1: Emission data used to calculate carbon footprints for the label. Cross-references to assumptions and methodological choices comprised in the emission data are specified separately in Table 2. Footprint including packaging, distribution and unavoidable waste calculated based on Sjörs et al. (2016).

	Assumptions & Methodological Choices
Emissions from LUC	Emissions from Land Use Changes (LUC) were generally not taken into account, due to a lack of data and methodological uncertainties.
*** Meat vs. dairy beef production system**	According to the restaurant´s responsible for procurement, all beef used could be assumed to origin from meat production systems.
*** Carcass vs. product weight**	The factor carcass weight to product weight was assumed to be 0.7.
*** Allocation by-products**	For beef all emissions were allocated to the meat, none to the waste products (e.g. bones).
**** Allocation beef vs. dairy**	For dairy production systems physical allocation was applied: 85% of emissions were allocated to milk, 15 % to meat.
*** Allocation beef cuts**	An average emission value was applied for all cuts and products of beef.

Table 2: Assumptions and methodological choices comprised in the used emission data.

2.3 Label Design

As a starting point for the label design, I reviewed scientific literature on labeling of food products and existing labeling schemes. Drawing on experiences with the use and effect of previous labels allowed me to identify a number of label characteristics which were found to work well or less well. I derived a list of design criteria from these characteristics in combination with context specific requirements. To determine the numerical scale of the label I analyzed the footprints, which I found during the first three weeks of the reference phase.

Based on the developed criteria and the knowledge gained from the literature research I generated four different draft designs. One of them did not fulfill all design criteria and was therefore dropped. For evaluation of the remaining three, I pre-tested these on a focus group of randomly selected guests at Kårrestaurangen. People were shown the adapted menus and asked to make a hypothetical choice. They were further asked whether they paid attention to the additional information, whether they knew what it was about and whether it played a role in their choice. Finally, they were encouraged for open feedback and opinions. Apart from the focus group, I took feedback from the restaurant´s management team as well as involved researchers into account for further improvements and selection of the final design. In a last step before implementation, I re-evaluated the improved design against the initial criteria, integrated and tested it in the restaurants IT systems.

2.4 Data collection

The consumption data was mostly collected automatically via the university´s electronic payment system. All students are registered in this system with a personal ID number. As the study objects did not know they were participating in an experiment, it had to be assured that their personal information was made anonymous. The Swedish research council´s guidelines on research ethics (Hermerén et al. 2011) suggest that the data resolution should by no means allow to reveal an individual identity. For this purpose anonymous ID numbers were randomly assigned to each individual, replacing their real personal numbers, before I received them. Besides the ID, gender, year of birth, product, date and place of consumption were documented for every data point.

Additionally this information was available for historic consumption data before the start of the experiment. This allowed me to back up observations from the reference phase with historic data from November 2015 to January 2016.

Unfortunately some data could not be collected electronically. The payment system does not distinguish between the three different types of salads people can choose from. They are all registered as *Classical Salad*. The same holds true for the distinction between pea soup and the regular meat dish, which are both sold under the header of *Classical Meat* every Thursday. To compensate for this gap, I collected the receipts proving a visitor´s payment on different stacks for the different choices and counted them manually. This however, implies the assumption that guests place their receipts correctly, and moreover, it does not enable to re-connect the information to single individuals. This posed both, a challenge and restriction to the data analysis. I used the shares among the competing options to calculate a weighted average footprint for these data points.

2.5 Data Analysis

When it comes to the analysis of the respective data, I took several, sometimes iterative steps. For example, to allow for group-wise comparison along the characteristics known about the individual study objects, I grouped them according to their frequency of visits, gender, age and dietary habits. When establishing these groups one would ideally consider a content-wise meaningful distinction, while keeping similar and large enough sample sizes for all groups. This however, is limited by the given gender and age structure of the visitors. The gender ratio is with 70% males and 30% females rather unbalanced, meaning a relatively small sample size for females.

Moreover, the fact that only the consumption behavior of students could be observed, poses limitations to the comparison of age groups. As can be seen from the age distribution in Figure 2, the vast majority of samples are in their mid twenties, whereas visitors to the higher end, above 30 years of age, are found only sporadically.

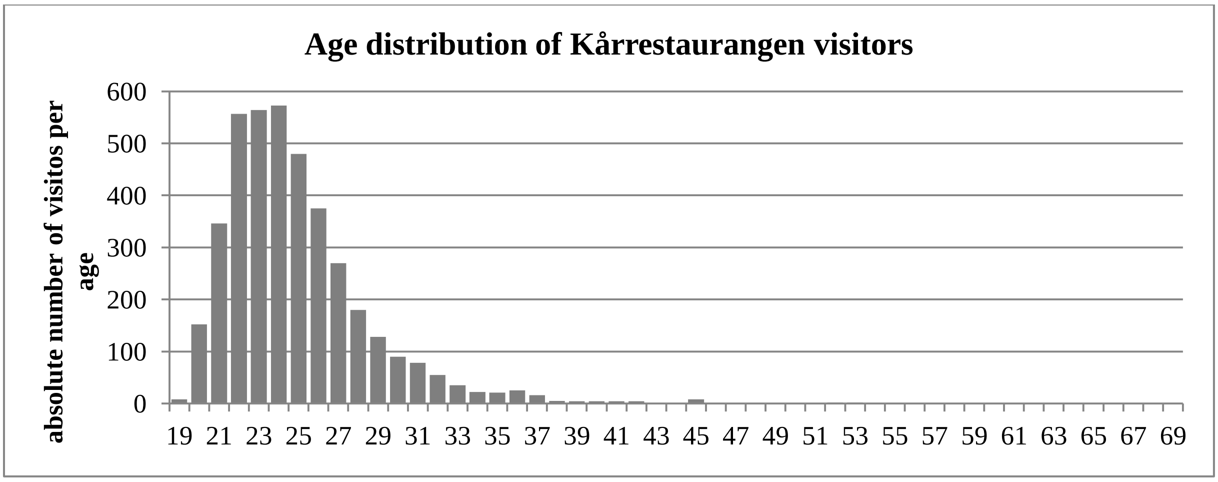

Figure 2: Age distribution of visitors at Kårrestaurangen during both experimental phases.

Establishing age cohorts was therefore a trade-off between meaningful grouping on the one hand and large enough sizes sample on the other. I chose to set age groups as presented in

Table 3.

Age Group	from age to age	Amount of individuals: Reference Phase	Amount of individuals: Label Phase	amount of individuals: returning in both phases
Group 1	19-22	722	812	1 063
Group 2	23-25	1 140	1 223	1 617
Group 3	26-29	692	694	953
Group 4	30-69	270	286	383
Total		2 824	3 015	4 016

Table 3: Age groups and amount of visitors at Kårrestaurangen per group.

Furthermore, I assigned individuals to groups of dietary habits. For this purpose I first analyzed people´s consumption patterns prior to the label in order to establish content-wise coherent groups. These are the following four: *Carnivores* chose only meat dishes. The group *meat&fish* chose between the classic meat and fish option only. A *mixed* diet includes vegetarian, fish and meat dishes. And finally *Pesco-vegetarians* comprise vegetarians and those who additionally or exclusively eat fish. Secondly, I had to define how many visits per person were sufficient in order to determine their dietary habit. I did this by testing how the shares between the habits change with an increasing minimum criterion of two to seven visits. I found that a minimum of four traceable data points per person (i.e. without salads) was the best available trade-off between degree of precision and large enough sample sizes.

In order to be consistent throughout my work, I applied this minimum criterion of four visits per phase also to distinguish between frequent and occasional visitors.

Another complication to the analysis is that the offered dishes were not the same during reference and label phase. The emission intensity of each phase´s offer, however, inevitably determines emissions from consumption. Therefore the emission intensity of the offer in each phase had to be evaluated. For this purpose the seven daily choices were given weight according to their historic sales shares using consumption data from November 2015 to March 2016 (see Appendix Table 1, p. 57). The arithmetic mean over all days of a phase result in an average footprint per offered dish and per phase, as depicted in Figure 3.

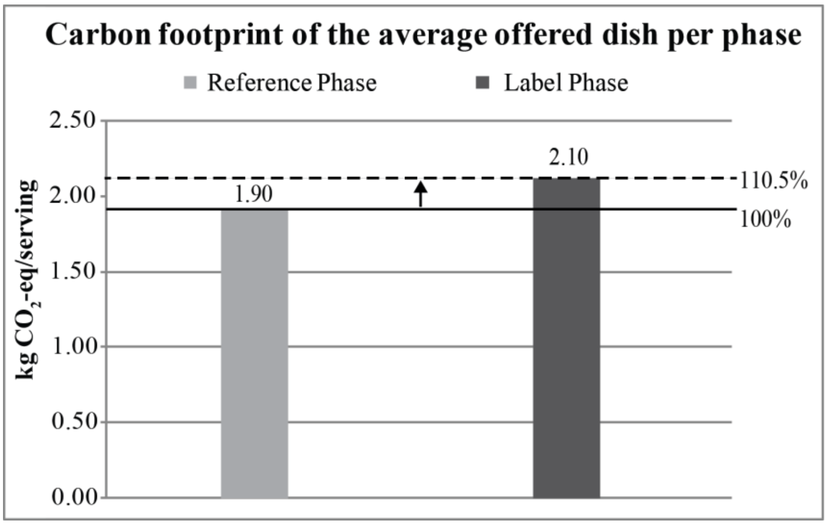

Figure 3: Carbon footprint of the average offered dish per phase.

On average the footprint of the offer during the label phase shows to be 10.5% higher than during reference phase. This obviously influences the footprint of people´s consumption during the label phase and thus has to be accounted for in the subsequent analysis.

To isolate the difference in offer and make a potential effect of the label visible, I therefore compared expected emissions with actual emissions. This means for every day during label phase I calculated the expected average footprint by weighing the seven daily choices according to their historic sales shares. If people continued to consume as was the case before prior to the label, the observed average footprint per serving should be approximately equal to the expected footprint. Differences between expected and observed value can hence be attributed to changes in consumer behavior due to the label.

3 LITERATURE REVIEW: CARBON FOOTPRINTS

3.1 Carbon Footprint Concept

3.1.1 Definition

The concept of the carbon footprint emerged out of the controversially discussed ecological footprint, introduced by Wackernagel and Rees in the 1990s (Pandey and Agrawal, 2014; Swedish Environmental Protection Agency and Swedish Chemicals Agency, 2011). Although, to date different definitions of the concept can be found, it is widely accepted that the carbon footprint refers to the quantity of direct and indirect GHG emissions released into the atmosphere from an individual, organization, product, process or event, within specified system boundaries (Pandey and Agrawal, 2014; Quinteiro et al., 2014).

3.1.2 Method

Carbon Footprints are based on life cycle assessment (LCA) data for the respective products and services. (For background information on the method and application of LCA please see Baumann and Tillman, 2004). Regarding the method to generate these footprints from life cycle impact data, approaches vary. Despite some early discussion on the wording, asserting that carbon footprint would imply to exclusively cover carbon dioxide emissions, it is now common practice to include all greenhouse gasses that are covered by the Kyoto Protocol. The reporting unit for carbon footprints is the mass of carbon dioxide equivalent (CO_2-eq) based on 100 years global warming potential (GWP) of GHG according to the Intergovernmental Panel on Climate Change (IPCC). However, regular updates of these figures have led to discrepancies of footprint results over the years. Also choices regarding which life cycle stages to include in the measurement, are not consistent. Taking a cradle-to-gate approach covers only emissions from raw material extraction to product manufacturing and packaging, while a cradle-to-grave perspective includes the entire life-cycle from primary materials, through production, use-phase to final disposal (Quinteiro et al., 2014). Aiming for harmonization in the applied methods, the International Standards Organization (ISO) provides "requirements and guidelines for the quantification and communication of the carbon footprint of a product" in their ISO/TS 14067:2013 standard.

3.1.3 Advantages and Disadvantages

The variety of different stakeholders calculating carbon footprints in different ways has the disadvantage that results are of limited consistency and comparability. Another weakness of the concept is that results are not exact. Accuracy decreases especially with increasing levels of aggregation and involved assumptions. Moreover, looking at the quantity of emissions only, disregards that different emissions can have unequal impacts in distinct geographical locations. On the bright side however, it has to be acknowledged, that the concept is already relatively well recognized and ever more carbon footprint data is available. A definite strength is that footprints can be applied at any scale, from a single product, to individuals, companies, entire sectors or countries (Swedish Environmental Protection Agency and Swedish Chemicals Agency, 2011). With the basic footprint data available, it is even relatively easy to provide footprint estimates at more aggregate levels.

3.1.4 Application

Choices in method as well as trade-offs between strengths and weaknesses will to some extent depend on the purpose of the footprint calculation. Information provision to consumers, as applied in this case, is only one application of carbon footprints (Quinteiro et al., 2014). They are also increasingly popular as a means of product differentiation and marketing. On the supply side, carbon footprints allow producers to identify undetected emission hotspots and opportunities for improvement.

3.2 Food´s impact

Food products as a group are extremely heterogeneous. The product range is sheer endless and within that the variety of production systems is large. Hence also the environmental impact can differ a lot from one food product to another. Nonetheless, Sonesson et al. (2009) identify some common characteristics. A first aspect is, that the mayor impact of agricultural products commonly occurs during the production stages, while use phase and disposal are minor contributors. Besides, for food - as opposed to many other products - fossil carbon dioxide (CO_2) plays less of a role, while biogenic GHG emissions are higher. In the production of plant-based products as well as monogastric animals, i.e. pork and poultry, nitrous oxide (N_2O) is often the main contributor to emissions. For ruminant animals it is methane (CH_4) (Sonesson et al., 2009).

Products from ruminant animals, such as beef, mutton and dairy, have generally higher emissions than other food products. In total livestock production is responsible for about two thirds and hence the majority of all agricultural emissions (Gerber et al., 2013). This is for two reasons (Gerber et al., 2013): Firstly, beef and dairy have a very low energy conversion efficiency. In other words, cattle need large amounts of energy input from feed in order to deliver a comparably small amount of energy output in the final product. Feed production is therefore one main reason for cattle´s high footprint. Secondly, ruminant animals digest their feed by undergoing a process of enteric fermentation, which releases large amounts of methane to the atmosphere. Thereby emissions are the higher, the less efficient production systems are (Nguyen et al., 2010). Particularly the free pasture systems in Latin America are extremely emission intensive (Opio et al., 2013).

Production systems which are stereotypically often viewed as more environmentally friendly are organic and local systems. Although only limited research is available in this regard, it can be said that there is no clear trend favoring organic and/or local systems over conventional ones (Bos et al., 2014). Instead results differ from specific product to product.

Moreover, also other factors such as land use change and transportation can play a role. Due to methodological uncertainties and a lack of data, emissions from Land Use Change (LUC) were so far hardly taken into account. However, they can increase emissions drastically (Cederberg et al. 2011).

Transportation often plays a smaller role than expected (Sonesson et al., 2009). Flight cargo of perishable products from global supply chains can be an exception. So are inefficient consumer logistics, especially in developed countries where short distance groceries are often done by car (Sonesson et al., 2009).

Furthermore, cooking can play a role on an aggregate level, food waste may release methane if kept under anaerobic conditions in landfills and packaging may be of significance for some products, with conflicting interests in product protection and impact of packaging materials (Sonesson et al., 2009).

4 LITERATURE REVIEW: LABELING OF CONSUMER FOOD PRODUCTS

Grunert et al. (2014) claim that it is not impossible to take environmental product considerations into account without the help of a label. In the food context for example an often encountered heuristic is to give preference to locally grown and/or seasonal produce. Nonetheless, this is based on uncertainty and does also require some sort of product information, e.g. its origin (Grunert et al., 2014). Neither can eco-labeling be sufficient to achieve sustainable production and consumption systems as an isolated measure on its own. Koos (2011) criticizes that drawing attention to environmentally friendly products would even imply a rather constrained understanding of sustainable consumption, neglecting the importance of reducing consumption overall. However, sustainability labeling has been acknowledged as one step towards a more sustainable industrial society (Koos, 2011). Since the introduction of the first eco-label, the German "*Blue Angel*" ("*Der Blaue Engel*") in late 1970´s, a wide range of product labels entered the market over past decades. Some of the more prominent examples are Fair Trade, Rainforest Alliance, FSC Forest Stewardship Council, MSC Marine Stewardship Council, EU Eco-Flower, EU Energy Efficiency label for household appliances, US Energy Star for electronics or nutrition guideline daily amounts.

The subsequent section will first review how these labels can be classified. Thereafter an overview of existing climate labeling schemes in the restaurant & catering sector will follow. Chapter 4.3 shows what has been found in terms of effects of past approaches, before challenges and requirements to carbon labels will be outlined.

4.1 Typology of product labels

When it comes to characterization and categorization of labels there are many ways to do so and no commonly agreed typology is currently in place. Categorizations found in literature were done under a number of different dimensions. Figure 4 gives an overview of a possible way of categorization, derived from a comprehensive literature review.

Considering the content a label covers, the overarching group of sustainability labels commonly tackle ethical or environmental issues separately. Environmental labels are often further distinguished in production labels, i.e. certification for more environmentally friendly production practices than comparable average products; and percentage labels, indicating a certain percentage improvement compared to industry average. Climate/carbon labels are to be seen as a more narrow sub category of environmental labels. Regarding the way labels are administered (lower half of the figure: governance) distinctions are made between voluntary vs. mandatory schemes and their way of validation. The label developed for this study can thereby best be classified as a voluntary, first-party carbon product label.

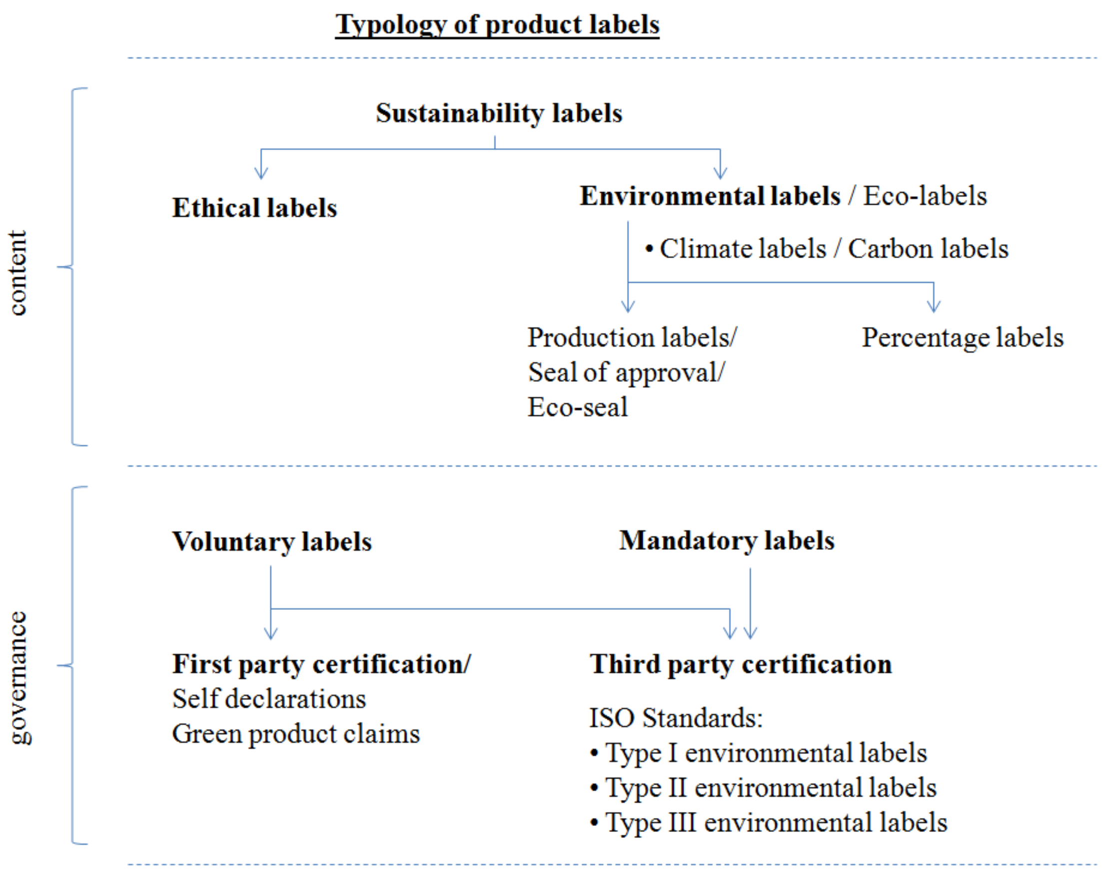

Figure 4: Typology of product sustainability labels, own representation based on literature review (EPA Environmental Protection Agency U.S., 1998; GEN, 2004; Harris, 2007; Blomqvist, 2009; Horne, 2009; Bratt et al., 2011; ISO, 2013; Noblet and Teisl, 2015).

4.2 Climate Label Experiences in the Restaurant & Catering Sector

The 'eating out of home' sector has been given very little attention when it comes to eco-labeling in general and climate labeling in particular. One study found similar to this one, was done by Spaargaren and colleagues in 2013. They introduced carbon labels to a selection of choices in a canteen at Wageningen University, in Wageningen, the Netherlands. The experiment was conducted in several phases, testing different label set-ups. While in a first step a simple black & white label was introduced, the second phase comprised much more comprehensive interventions, far beyond the time and budget restrictions of my study. For example Spaargaren et al. used an information video, lunch suggestions and individual feedback on people´s personal footprint score. Their focus was thereby to observe, in quantitative as well as qualitative terms, how people´s habitual practices are influenced by these interventions. It is hence different form my study which is of quantitative character with focus on the climate change mitigation potential of the carbon label. Moreover, the consumers in Wageningen were mostly university employees, which means they have different socio-demographic characteristics than students. Also, the canteen does not serve warm lunches in the form of main dishes like Kårrestaurangen does, but rather warm and cold snacks, soups and beverages. Although only single items were labeled, Spaargaren et al. did assess the cumulative footprint of purchases per day and person. They found a small but significant decrease in average emissions per lunch of three per cent for the comprehensive labeling scheme (Spaargaren et al., 2013).

In another study Visschers and Siegrist (2015) found that the introduction of a climate-friendly choice seal in a university canteen in Zurich, Switzerland, significantly increased the sales share of the climate friendlier meals from 46 % to 56%, as opposed to unfriendly ones. Moreover, meals´ emissions were found unrelated to how they are ranked in taste. Neither did climate friendly choices affect consumer preferences or satisfaction. The set-up of their experiment and the demographics of the customer base is comparable to my study. Similarly, in support of the label itself, information posters were used. The study time was shorter and the number of daily choices smaller, however, Visschers and Siegrist also collected qualitative data on taste ratings and perceived environmental impact via customer surveys.

It is not indicated, though, that the labels used in the two studies presented above, were pursued beyond the experiments. Only one permanent labeling scheme of meals in a restaurant setting could be identified from the conducted online research. It was introduced by the Swedish Fast Food chain Max in 2008 (Upham and Bleda, 2009; Max Hamburgerrestauranger AB, 2015). The carbon footprint, shown as the numerical value in kg CO_2-eq (e.g. Figure 5 a), is displayed for every product choices on Max´ menu, from burgers to dips and desserts. Apart from information provision to their guests, the company has also been using this label as part of their sustainability strategy for marketing and image purposes (see Figure 5 b).

a b

Figure 5: Max Hamburgers: a) CO_2e-labeled product b) The "Green Family" - meat free choices (Sources: http://www.max.se/sv/ansvar/klimatdeklaration/ [15.04.2016] https://www.max.se/sv/Kampanjer/Just-nu-pa-Max/green-familjen/ [15.04.2016])

4.3 Use and effect of previous carbon labels

Previous research has mostly been concentrated on selected labeling schemes, especially the longer established and more popular ones like organic, fair-trade and animal welfare labels (Pelsmacker et al., 2005; Chatzidakis et al., 2007; Grankvist et al., 2007; Napolitano et al., 2008; Nguyen and Du, 2010; Janssen and Hamm, 2012; Grunert et al., 2014; Hainmueller et al., 2014). Only recently there has been increasing focus on climate labels (Upham et al., 2009; 2010; Vandenbergh et al., 2011; Vanclay et al., 2011; Röös et al., 2011; Spaargaren et al., 2013; Shewmake, et al., 2013, 2015; 2015b; Visschers and Siegrist, 2015). Similarly, when investigating consumer attitudes and behavior, most studies address selected aspects such as people´s willingness to pay, or self-reported awareness and intentions (Pelsmacker et al., 2005; Napolitano et al., 2008; Blomqvist, 2009; Janssen and Hamm, 2012; Grunert et al., 2014). Findings of these, however, are sometimes limited by gaps between models and reality or equally between people´s attitude and actual behavior (Chatzidakis et al., 2007; Vermeir and Verbeke, 2006; Röös and Tjärnemo, 2011; Shewmake, 2013; Shewmake et al., 2015). Less research has been done on the actual impact of labels, quantifiable effects on consumer choice and on the factors influencing consumers´ label use.

4.3.1 Consumption effects vs. supply side effects

Initially intended as a consumer facing policy, carbon product footprint labels are frequently said to have a dual effect. As mentioned before, on the downstream side of the food value chains, i.e. on the consumption side, footprint labels are a means of disclosing product information to consumers, which they cannot be expected to have else how. According to utility theory in economics, the consumer hence receives information about an additional utility he would yield from the purchase of the respective product, e.g. low impact on the climate, which may lead him to re-evaluate his product preferences and eventually shift product choices (Read, 2007). Secondly, carbon footprints are said to yield positive impacts in the upstream segment of supply chains (Clift et al., 2005; Spaargaren et al., 2013). It allows companies to identify and eliminate previously undetected inefficiencies, which reduce emissions along with cost in production, processing and manufacturing. Moreover, it stimulates competition in business-to-business (b2b) procurement. Despite lacking scientific evidence, several authors suspect the true value of carbon labeling to lie in the second, the supply chain effect (Upham, et al. , 2010; Larsson and Khan, 2011; The Economist, 2011; Quinteiro et al., 2014). This claim would indeed be supported by the developments around carbon label initiatives during the past decade. An initial boom in product labeling, especially in the grocery context, during the late 2000s has since dropped off. According to U.S. policy Expert Bill Sheehan (2014) in an online article for upstreampolicy.org, the assessment of footprints per se, however, did not decline. It shifted from consumer information to internal and b2b communication, invisible to the end consumer (The Economist, 2011; Sheehan, 2014).

Another group of actors that is found to increasingly make use of climate impact information for food items are organizations which give dietary advice (Pandey and Agrawal, 2014). These can be both, private businesses and public institutions. Regarding the latter, national governments or international bodies such as the World Health Organization (WHO) commonly express nutrition recommendation for citizens, and are thereby more and more considering aspects of sustainable food consumption. For example, the Nordic Council of Ministers dedicates a chapter in their *Nordic Nutrition Recommendations 2012* to this concern and suggest to distinguish between products according to low (less than 1 kg CO_2 / kg product), medium (between 1 kg and 4 kg CO_2 / kg product) and high (more than 4 kg CO_2 / kg product) climate impact (Nordic Council of Ministers, 2012). On the long term this may pose an additional, positive effect on GHG emission reductions in the food sector.

Whether or not carbon labels lead to a reduction in greenhouse gas emissions, and if so, how big this is, hence depends on a combination of short-term and long-term, direct and indirect effects, for all of which there is little evidence. For the purpose of this study, focus will further be given to the consumer side of effects.

4.3.2 Consumer characteristics determining label use

Drawing on literature, it can be said that there are three main variables determining the degree to which consumers change their purchase behavior. This is characteristics of the product, the person and the label (Noblet and Teisl, 2015). Regarding the product, price and product similarity were found to play an essential role in choice making (Vlaeminck et al., 2014). When it comes to personal characteristics of the individual consumer, a number of determinants come into play. Findings are consistent in that gender, education and socio-economic status have a significant effect on the use of environmental labels. Thereby females, people of higher education or higher status were found more likely to purchase labeled products (Grunert et al., 2014; Noblet and Teisl, 2015). Inconsistent are the results for the influence of age. Some suggest that eco-label use declines with rising age (Brécard et al., 2009), while others found that older survey respondents report a higher use (Grunert, et al. 2014), and yet again other studies have found an effect that follows an inverse U-shape, i.e. younger and older are less likely to buy 'green' than middle-aged (Noblet and Teisl, 2015). To which extent these discrepancies can be explained with peculiarities of the respective studies, e.g. measured versus self-reported use, or overall age distribution of grocery shoppers, remains unclear. Neither are these studies specific to carbon labeling and therefore of limited value for my study only.

Another relevant consumer characteristic is their motivation. Grunert, et al. (2014) distinguishes different levels of motivation. The most abstract level regards human values, whereby according to Vermeir and Verbeke (2006):

> "*In general, the values universalism, benevolence, self-direction, honesty, idealism, equality, freedom, and responsibility have been linked to sustainable consumption, whereas power, hedonism, tradition, security, conformity, and ambition were associated with less ethical or less sustainable consumption patterns.*"(Vermeir and Verbeke, 2006)

A less abstract form of motivation is concern. Climate change is generally found to be of rather low priority in people´s thinking and behavior in a day to day purchasing context (Upham et al., 2010). Finances, health, safety and social issues are usually consumers´ top most concerns (Upham et al., 2010). Environmental concern is correlated to socio-demographic and cultural variables (Grunert, et al. 2014): Females are found to be more concerned than male and concern rises with age. Among six European countries, Sweden showed to have the least concerned society. Grunert, et al. (2014) further suggest that Swedes´ low concern in combination with their high understanding of environmental issues causes them to distance themselves from the use of labels when shopping food.

Understanding is another determinant to label use (Grunert, et al. 2014). This includes understanding of the general issues addressed by labels, of the specific information communicated through a label, as well as understanding of which label stands for what. Beyond a certain threshold higher understanding indicates lower use of labels (Grunert, et al. 2014).

Other factors of influence may be, to which extent the consumer sees prestige in buying labeled products, the perceived availability of labeled products or the perceived effectiveness of a label (Grunert, et al. 2014).

4.3.3 Previously observed consumption effects

Considering the above, it appears surprising that according to a 2009 survey as much as72% of European Union citizens supports that a label indicating a product´s carbon footprint shall be mandatory (The Gallup Organisation, 2009). However, previous research has repeatedly shown that there is a gap between what people say and actually do (de Boer, 2003; Chatzidakis et al., 2007; Grunertet al., 2014). Upham et al., (2010) speculate that:

> "*...it would seem very unlikely that more than 10% of the [British] population would use a carbon reduction label as a basis for product selection across a substantial proportion of their purchases, without some external incentive such as reduced price*." (Upham et al., 2010).

Similarly Röös and Tjärnemo (2011) make an estimation of potential future buyers of climate labeled products in Sweden to be around 24%. This share for Sweden appears less impressive though, knowing that the overall purchases of eco-labeled products and services currently represent only a few percentage points of the country´s private consumption (2-3% in 2001) (Clift et al., 2005). Apart from these few estimations on the use of carbon labels, only one study attempted to answer the question by how much consumers are willing to reduce their consumption of high emitting products (Shewmake, 2013). The results for the U.S. American context indicate "*that if consumers were to learn the carbon impact of beef, they would decrease their beef consumption by approximately 3–4 per cent*" (Shewmake et al., 2015). As mentioned earlier, the study by Spaargaren et al., found a decrease in average emissions of canteen lunches by 3% as reaction to a comprehensive labeling and information initiative (Spaargaren et al., 2013). Visschers and Siegrist (2015) found the sales share of climate-friendly meals to increase from 46% to 56% after labeling them as such. Although there is little empiric evidence, previous research hence suggests that only small changes in the order of few percentage points can be expected from the introduction of a carbon label.

Moreover, the type of interventions and label design has shown to be crucial. For this reason the following two chapters will elaborate on label characteristics which were found to impede and support the success of a labeling scheme. From that I will subsequently derive criteria for the label design.

4.4 Challenges to carbon labeling

Even though carbon labeling is still a relatively young development, past experiences allow to clearly identify a number of barriers to its successful application. It has to be noted, though, that the existing literature body mostly focuses on label application in the context of grocery shopping, where the main decision for consumers is whether to choose a labeled product over a non-labeled one. By contrast in Kårrestaurangen all dishes on the menu are labeled, all in the same manner. This already eliminates some of the main obstacles to the use of carbon labels, like their availability on the one hand, as well as diversity and overload on the other (Horne, 2009; Röös and Tjärnemo, 2011; Grunert, Hieke and Wills, 2014). Similarly differences in product prices can be assumed irrelevant for this study, as prices before and after label introduction as well as among the offered options were the same. Fewer challenges remain to the application of a carbon label in a restaurant setting, making it appear a seemingly more ideal environment for carbon labels to be applied.

Understanding

Poor understanding of the information a label conveys hampers label use. Understanding was found to be significantly correlated to the user´s age, country of residence and education

(Grunert et al., 2014) and has shown to increase over time with continuous label exposure (Kanter, 2009).

Lack of context

The hardest part for consumers, in terms of understanding, was repeatedly found to be the interpretation of a given emission quantity expressed as the mass of CO_2-eq per unit or mass of product (Berry, Crossley and Jewell, 2008; Upham and Bleda, 2009; Upham et al., 2010; Sheehan, 2014). Putting emissions in perspective via the use of a reference value, normalization, or a scale may help to engage more meaningfully with the provided information.

Food is a sensitive domain

Sustainability concerns in food consumption compete with multiple personal factors such as health, taste or other sensory qualities. These are consistently found to be higher in peoples priority when choosing what to eat (Röös and Tjärnemo, 2011; Grunert et al., 2014).

Lack of personal benefit

Similar to fair-trade labels, which are of benefit to anonymous, distant farm workers, carbon labels benefit at the utmost future generations (Röös and Tjärnemo, 2011) but are not of private benefit to individuals (Cohen and Viscusi, 2012).

Feedback

Like personal benefit, labeling schemes commonly neither include personal feedback upon taking action. Although feedback may supposedly enhance label use, Spaargaren et al. (2013) could show for a temporary labeling experiment, that only few consumers consulted optional feedback.

Which message to convey

Research has shown that consumers are more likely to avoid negatively labeled products, such as toxicity warnings, than neutral or positive messages which are not of immediate benefit to themselves (Cohen and Viscusi, 2012; Noblet and Teisl, 2015). Also Spaargaren and colleagues conclude that: "*Just offering labels without a normative reference will not do.*" (Spaargaren et al., 2013). At the same time however, they point out that that this shall be done in a non-directive, discrete manner, to avoid repellent reactions.

4.5 Recommendations for carbon labeling

Besides the challenges carbon labels have been facing during their short history, causing large-scale initiatives like the one of UK supermarket chain Tesco to fail, a number of opportunities to improve future schemes came to show.

Comparison across product types

In order to decrease the emissions from the entire food system as much as possible, rather than of a single product system, a label shall allow comparison across product types (Röös and Tjärnemo, 2011), i.e. stimulate consumers to switch form beef and dairy products to other types of meat or vegetarian and vegan alternatives.

Label placement

In order for consumers to act upon the label, the information needs to be provided where and when choice making happens (Spaargaren et al., 2013), i.e. at the self, on product itself, on the menu or at a buffet.

Traffic light color coding

The use of traffic light color coding is widely supported (Berry et al., 2008; Upham and Bleda, 2009; Upham et al., 2010; Röös and Tjärnemo, 2011; The Economist, 2011; BBC News, 2011; Bittman, 2012; Spaargaren et al., 2013; Vlaeminck et al., 2014). A combination of traffic light colors and an absolute number of emissions was found to be most effective (Röös and Tjärnemo, 2011; Spaargaren et al., 2013). Apart from first experiences with carbon labels (Berry et al., 2008; Vanclay et al., 2011; Spaargaren et al., 2013; Vlaeminck et al., 2014), the success of nutrition labels as used in the UK, and the European energy efficiency label for white goods has shown traffic light colors to work well (European Parliament and Council, 2010; Upham et al.; 2010).

Self explanatory character

Moreover, a label should ideally carry is a self-explanatory character, i.e. the user should immediately and intuitively comprehend what the label communicates.

Background information

Several authors suggest that the success of carbon labels may be enhanced by the provision of additional information, beyond the label itself (McEachern and Warnaby, 2008; Upham and Bleda, 2009; Spaargaren et al., 2013; Grunert et al., 2014).

5 Label Design

5.1 Design Criteria

In order to approach the design process of the label in a structured way, the above identified challenges and recommendations for carbon labels from literature, combined with context specific aspects were translated into a number of criteria which the label design should fulfill. I defined nine criteria and specified them with sub-requirements. They are presented in Table 4.

Criteria	Specifications
Scientific	• Scientifically reliable • Consistent • Transparent • Reproducible
Based on Calculated Carbon Footprint values	• Value translates into unambiguous & distinct visual representation
Numerical Scale	• unit: comprehensible, reflective of degree of precision • defined reference values (min., max.) • various options: relative, absolute, normalized, ordinal, interval, ratio scale • put in perspective
Simplicity	• easy to understand • intuitive • no information overload • no prerequisites required to understand what is better, what worse
Graphic Display	• eye catching • colors (traffic light colors) • shapes
Customized to the Restaurant´s Menus	• integrated into menus • applicable to different ways/places of menu display
Informative Value	• convey a clearly defined message • fact based (preventing (miss)-interpretation) • provide choice guidance • allow for comparison between meals • label has to speak for itself (additional info only as support function)
Awareness & Educational Value	• inform and increase awareness on the food sector´s impact • allow to become familiar with the concept of Product Carbon Footprints • Allow comparability with other labeling schemes (use of CO_2-eq figures)
Additional Information	• transparency • potential FAQ

Table 4: Criteria for the label design, identified from a literature review on previous research.

5.2 Design Alternatives

Combinations of the identified criteria were developed into four different draft designs, which will be presented in this section.

5.2.1 Design 1: Footprint color bars

For this design a simple layout was chosen. Bars of 16 length-intervals corresponding to a dish´s emissions, colored in seven gradients of traffic light colors were shown for each dish (see Figure 6). As elaborated in the above literature review, traffic light colors have been found to work well for such product information. However, the sole use of colors, perhaps in bars of meaninglessly increasing length, as of the energy efficiency label for white goods of the European Union (European Parliament and Council, 2010) disregards the distance between values. Therefore, an interval scale with according coloring and length of bars adds value for the consumer, who may then instantly compare between choices or against a reference value. Moreover, the abstract, rectangular bars were complemented with an icon symbolizing that the information was dealing with carbon footprints. To date there is no generally established symbol for carbon footprints. However, it seems the obvious choice to use a footprint symbol, as it is most likely associated with the carbon footprint of a product (Upham and Bleda, 2009) and has frequently been used in previous schemes and studies (Vlaeminck et al., 2014; Carbon Trust, 2016).

Figure 6: Sample of label design 'Footprint Color Bars'

Label intervals and colors were set based on the frequency distribution of the offers´ footprints. Dishes with meat from ruminant animals have a footprint higher than 2 kg CO_2-eq. The label shall in essence communicate that the consumption of these products is exceedingly worse for the climate over others and needs to be reduced. For this reason, I chose to use red for footprints above 2 kg CO_2-eq. These red intervals have a larger width, of 1 kg CO_2-eq each, while lower intervals show a higher resolution, in order to give credit to a finer distinction between the majority of dishes occurring below 2 kg CO_2-eq (Figure 7).

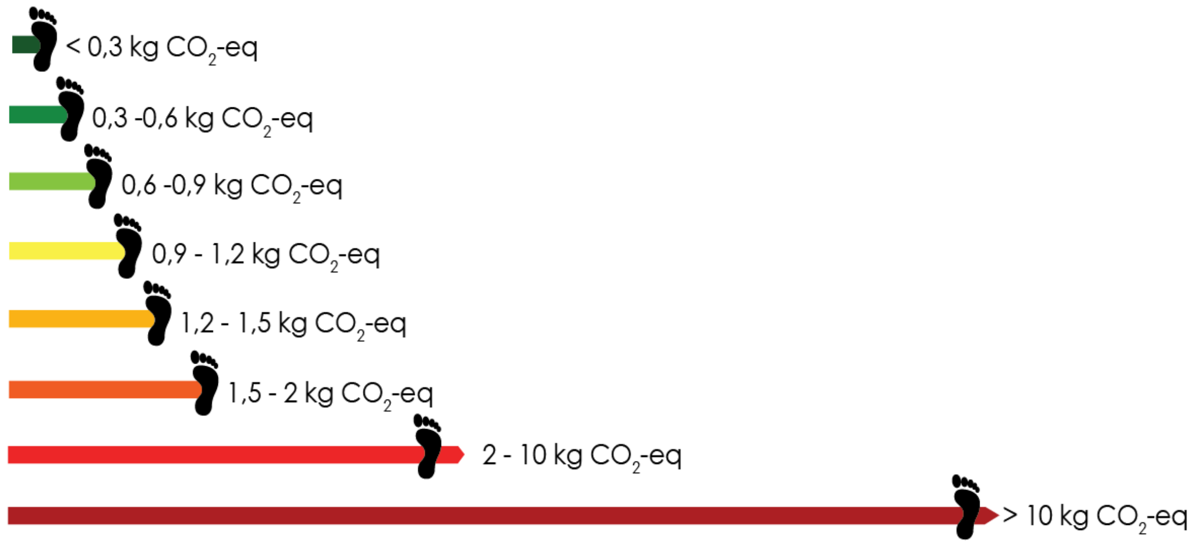

Figure 7: Label Intervals for label design 'Footprint Color Bars'

In addition to the label itself, the scale is given at the bottom of the menu. It shows intervals, colors and introduces a reference value to the scheme. As reference value I chose the footprint of an *average Swedish meal*. This value was derived from Bryngelsson and colleagues (2016) research on the yearly per capita emissions related to food consumption. From the annual 1.8 tons CO_2-eq per capita, beverages, snacks and sweets were subtracted, because they are not contributing to the observed dishes. The remaining 1.5 tons per capita were distributed over three approximately equal meals per day. The resulting average footprint per meal amounts to about 1.4 kg CO_2-eq.

5.2.2 Design 2: Walking Footprints

A second layout idea is similar to the above, but less abstract in its design. The bars are replaced with a track of footprints over the entire length of the scale. Depending on the amount of a dish´s emissions a certain number of foots appear in the respective color, while the others remain gray (see Figure 8). The main difference to the above is that with every labeled item not only the specific value but also the absolute maximum is given through the grey continuation of the scale. This can be of advantage when the direct comparison between dishes is not possible, for example when the menu is set up in such a way that not all items are listed below each other, but on separate pages.

Figure 8: Sample of the label design 'Walking Footprints'

5.2.3 Design 3: Bigfoot

A third draft follows the idea of existing approaches like The Carbon Trust product labels or the label used by Vanclay et al. (2011). It shows a bigger footprint symbol (see Figure 9), which is colored depending on the emission value and showing the numerical emission value. This design offers less information to the user, as it is missing the component of direct visual comparison between meals. The user hence has to rely more on the numerical value to interpret the information. The sequence in which the colors appear may be less clear.

Figure 9: Sample of the label design 'Bigfoot'

5.2.4 Design 4: The 2°C Meal

A fourth design takes a completely different approach than the above. It is based on the idea to relate the greenhouse gas emissions of a single meal to the target of a maximum increase of the global average surface temperature by 2°C compared to pre-industrial levels, as agreed by at the UNFCCC Conference of Parties in Paris in December 2015 (European Commission, 2016). Each dish on the menu would be labeled with the temperature increase corresponding to its emissions (see Figure 10). What makes this an attractive idea, is on the one hand that the Paris climate negotiations are just recently past and what came to be known as the '2°C target' continues to be a pressing issue causing public awareness and discussion. On the other hand, relating an everyday activity of a single individual, such as eating, to a commitment made by society as a whole, puts the information of product carbon footprints in a perspective that is clear and straightforward in its message. However, as Upham and colleagues (2010) point out, further research is required on how to communicate tight future carbon budgets as attractive choice guidance and vision to the individual. Another challenge to that is the non-linear relation between emissions and temperature increase, which complicates the label´s interpretation for the consumer. A 4°C meal for instance does not necessarily cause double the emissions of a 2°C meal, or could not be simplified to being "twice as bad" for the climate.

Apart from that, it is not straightforward to bridge the gap between emissions caused by a single meal and the global temperature increase in the far future. Scientific estimations of the remaining carbon '2°C-budget' were made by the United Nations Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2013). These however, are of cumulative character and involve a high degree of uncertainty. Separate regions, nations or institutions have set their own science based objectives. For example, the European Union adopted targets to roughly halve its agricultural non-CO_2 emissions by 2050. Broken down to a per capita level this would allow methane and nitrous oxide emissions of 500 kg CO_2-eq per person in 2050 (Bryngelsson et al., 2016). Nonetheless, this is still far from deriving a temperature increase from the emissions of a single meal eaten today. Overall, too many assumptions would have to be made to claim scientific rigor and provide a convincing argument to consumers. As also suggested by Upham and colleagues (2010), further research on such an approach to carbon labeling is desirable.

For the draft, I claimed a linear correlation between emissions and temperature increase and randomly assigned temperatures to emission intervals. However, as this is not truthful, the design does not meet the defined label criteria of scientific reliability and was therefore not considered further in the process.

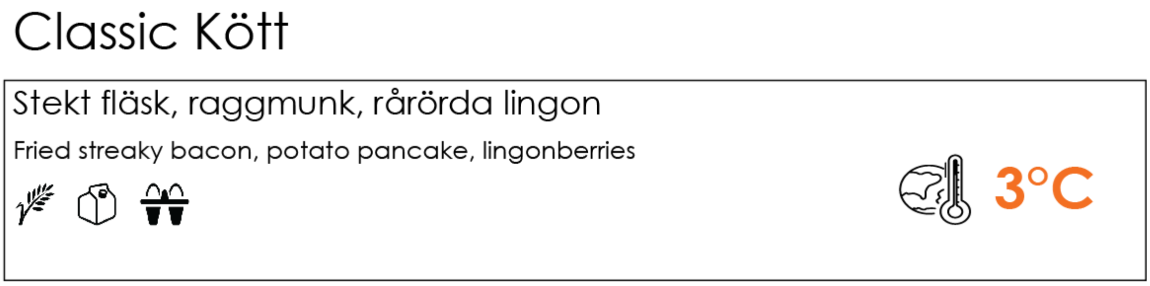

Figure 10: Sample of the label design 'The 2°C Meal'

5.3 Design Selection

To choose a final design, a number of randomly selected visitors at Kårrestaurangen were asked to evaluate the three remaining drafts. Table 5 sums up people´s preferences.

	Design 1 **Colored Bars**	**Design 2** **Walking Footprints**	**Design 3** **Bigfoot**
Number of votes for preferred design	11 out of 13	2 out of 13	0 out of 13

Table 5: Overview of the results from focus group interviews regarding design selection.

Design 1, *'Footprint Colored Bars'*, was clearly preferred by the majority of the asked visitors. Its sleek and clean layout was said to make it the clearest, easiest and most straightforward to capture. Also the easy comparison between dishes was welcomed. This strong preference was also supported by the restaurant´s management team, as well as by researches in the relevant field at Chalmers University. I therefore decided to further develop and implement Design 1. A sample of the final layout of the restaurant´s print menu is shown in Figure 11 below.

KÅRRESTAURANGEN

Classic Vegetarisk

Bami goreng, nudelwok, wokad broccoli & sesamfrön
Bami goreng, noodle wok, wooked broccoli & sesame seeds

0.2 kg CO_2-eq

Classic Sallad

Ädelost, valnötter, puylinser & äpplevinägrett
Blue cheese, walnuts, puy lentils & apple vinaigrette

0.8 kg CO_2-eq

Blåmussel- & torskceviche, gurka, chili & lime
Mussel & cod ceviche, cucumber, chili & lime

0.4 kg CO_2-eq

Stekt sidfläsk, rostad kål & Västerbottenostkräm
Fried bacon, roasted cabbage & Västerbotten cheese crème

1.3 kg CO_2-eq

Figure 11: Sample of Kårrestaurangen print menu from 13.04.2016.

6 RESULTS

Following the results of the data analysis will be presented. Besides some general descriptive analysis, this shall first and foremost clarify if and how big of an effect the carbon footprint label had on consumer behavior. These results will be presented both, aggregated over the entire sample as well as for groups of selected characteristics. Moreover, insights shall be gained on how the factor of taste influences choices and the label´s effect.

6.1 General statistics

6.1.1 Sample sizes

The collected data show that during both experimental phases the consumption behavior of about 3 000 individuals was observed in each restaurant. Thereof only roughly 40% were considered frequently returning customers, with more than four purchases per phase and restaurant. The ratio between males and females is about 70% to 30% in Kårrestaurangen. The control restaurant EXPRESS has slightly less female visitors. Table 6 gives an overview of the respective sample sizes.

	Kår Reference Phase	**% of total visitors**	**Kår Label Phase**	**% of total visitors**	**EXPRESS Reference Phase**	**% of total visitors**	**EXPRESS Label Phase**	**% of total visitors**
Total number of visits	12 326		14 683		12 394		13 727	
Total number of visitors	2 824	100%	3 015	100%	2 997	100%	3 124	100%
Frequent visitors (>4x/phase)	1 077	38.1%	1 229	40.8%	1 166	38.9%	1 291	41.3%
Male	1 992	70.5%	2 108	69.9%	2 239	74.7%	2 259	72.3%
Female	832	29.5%	907	30.1%	758	25.3%	865	27.7%

Table 6: Overview of sample sizes in Kår(-restaurangen)and EXPRESS per phase for number of visits, distinct visitors, frequent visitors, male and female.

Regarding the figures presented in

Table 6 it has to be mentioned that less than half of the individuals visiting during the reference phase came back during the label phase. This was the case for 45% at Kårrestaurangen and 48% at EXPRESS. Within each phase; around one third of the students visited both restaurants (34% during the reference phase and 35% during the label phase).

6.1.2 Groups of dietary habits

As explained in Chapter 2.5, frequent customers were assigned one of four groups of dietary habits according to their observed consumption pattern before label introduction: : *carnivores*, *meat&fish* eaters, *mixed* diet and *pesco-vegetarians*. Figure 12 shows the shares of these groups for the entire sample as well as separately for both genders. Males and females show very different habits. Among males the share of carnivores and meat&fish eaters together makes up 70% while this is the case for only about 40% of females. Only 9% of men were identified as vegetarians. Compared to that, the share of female vegetarians is 22%, while only 3% chose exclusively meat. Hence, it results that more men show animal-product-based consumption habits than women do. To which extent this result is peculiar to the relatively young population of university students remains uncertain at this point, and would be an interesting question for further research. Separate results for the distinguished age groups indicate though, that men tend to decrease meat consumption with increasing age.

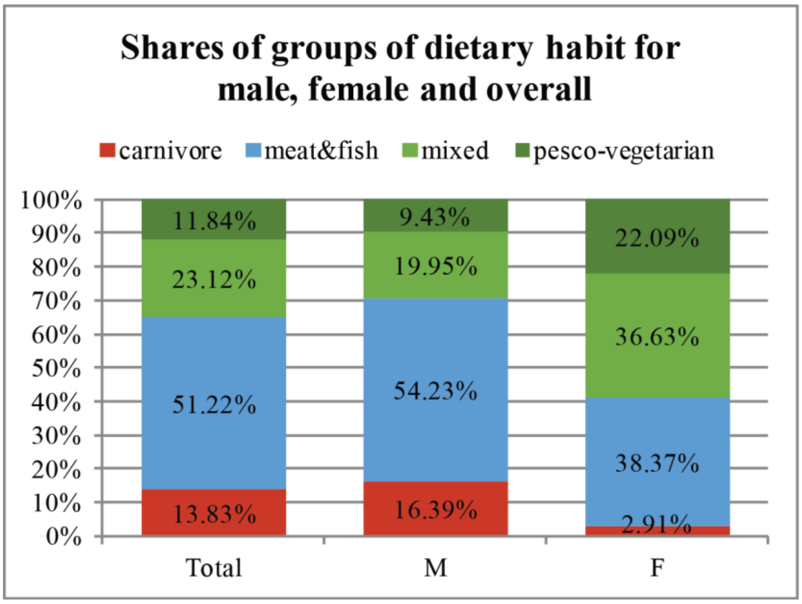

Figure 12: Shares of groups of dietary habit in total, for males and females. Note that due to the unequal gender distribution among visitors who´s dietary habits could be identified (80:20), male´s habits have the dominant influence on the overall shares.

6.1.3 Sales shares of product groups

The dietary habits are also reflected in the sales shares of the five offered product groups: *Classic Meat, Classic Fish, Classic Vegetarian, Classic Salad, and Week´s Soup*. While on average more than half of the men choose the meat option, both before and after the label introduction, less than 30% of women did. Females show a higher preference for all four remaining options, in particular for Classic Salad which in itself comprises a meat, fish and vegetarian choice. The available data, however, does not allow to make this distinction on the level of the individual. Results are depicted in Figure 13.

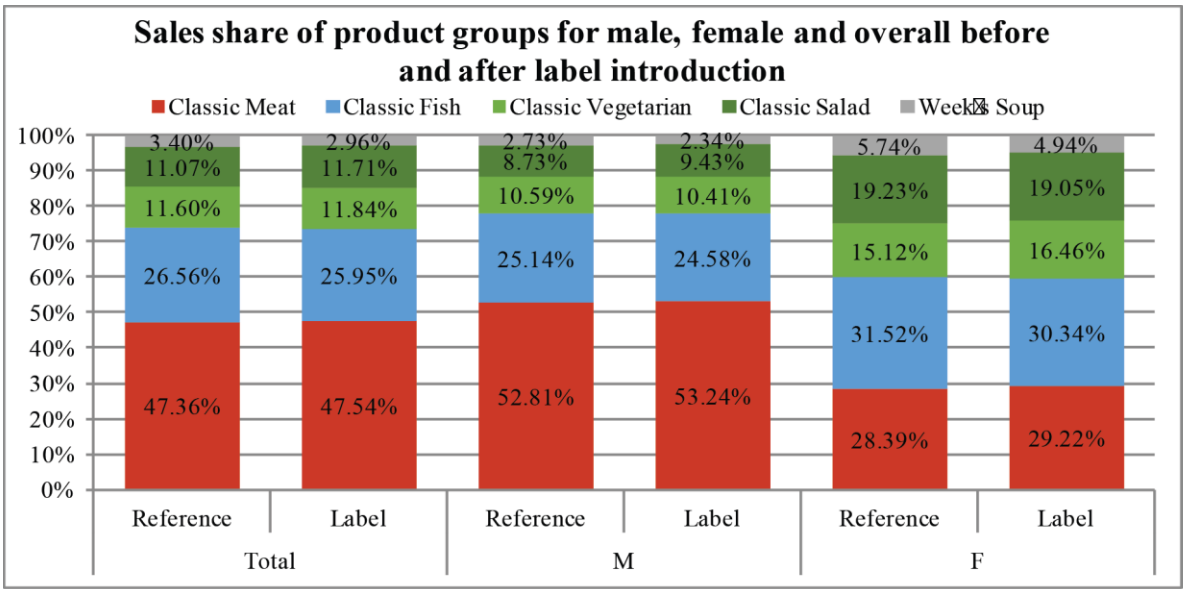

Figure 13: Sales share of product groups in total, for males and females before and after label introduction. Note that due to the unequal gender distribution among the overall sample (70:30), male´s choices have the dominant influence on the overall shares.

6.2 Overall emissions

6.2.1 Total cumulative emissions

In absolute numbers, the cumulative emissions resulting from all meals consumed during the course of six weeks (28 days) increased from 23.5 metric tons of CO_2-eq during the reference phase to 42.2 metric tons of CO_2-eq after label introduction. (The respective graph can be seen in Appendix Figure 8, p. 57.) This however, does not account for the fact that the offer was more emission intensive after the label had been introduced (as explained in Chapter 2.5 Data Analysis, p. 12). A potential effect of the label may therefore not be visible on a cumulative level.

6.2.2 Emissions per serving

To make potential label effects visible on a per meal level, the expected emissions during the label phase were compared to actual emissions (as explained in chapter 2.5 Data Analysis, p. 12.) The arithmetic mean of the difference between expected and observed emissions across all days during the label phase, is found to be -2%. This means on average emissions per serving reduced by 2%. However, the observed values are widely scattered around the mean. The standard deviation s calculated according to the below formula is 12.17%.

$$s = \sqrt{\frac{\sum(x_i - \bar{x})^2}{n-1}}$$

Whereby s is the standard deviation, x_i is the value of each day, $\bar{x}$ is the mean of all days, n is the number of days. Hence no effect can be derived from this result.

6.3 Group-wise comparison

6.3.1 Frequent visitors

For those visitors, who return to Kårrestaurangen on a frequent basis, as opposed to occasional guests (less than 4 visits during the label phase) no effect could be seen either. The average reduction among frequent visitors is 1.04% with a standard deviation of 10.28%.

6.3.2 Gender

Before the label was introduced, the average footprint among female visitors was 1.6 kg CO_2-eq per meal and 2.0 kg CO_2-eq per meal among male visitors. This is shown in Figure 14. Hence it can be observed that women generally follow a considerably less GHG emission intensive diet, than men do. This is also reflected in the differences between their consumption patterns as previously shown for dietary habits (Figure 12) and sales shares of product groups (Figure 13).

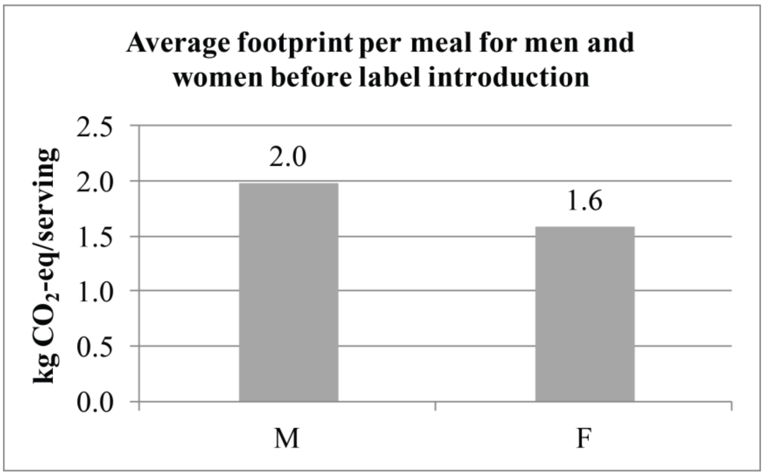

Figure 14: Comparison of average footprint per serving for males and females.

Apart from different baseline emissions, previous studies suggested that there is a significant difference between males and females and their reaction to environmental product information (Grunert et al., 2014; Noblet and Teisl, 2015). However, the results generated my experiment can neither confirm nor contradict previous findings. The average reduction for men was found to be 2.23% with a standard deviation of 11.56% and 1.97% for women with a standard deviation of 16.37%.

Moreover, it occurs that the reaction to the label depends on the absolute level and thus the label color of the day´s maximum footprint, as presented in Figure 15. While in general a considerably smaller share of females chooses the most emission intensive option than is the case for male, it seems both were initially slightly more attracted to choose the day´s maximum when it had high emissions (meaning it would have been labeled in red color) than when it had medium emissions (i.e. labeled in orange or yellow). Across both genders it could be observed after label introduction, that the share of those choosing the day´s maximum decreased on days where the maximum label was red and increased for orange/yellow maximums.

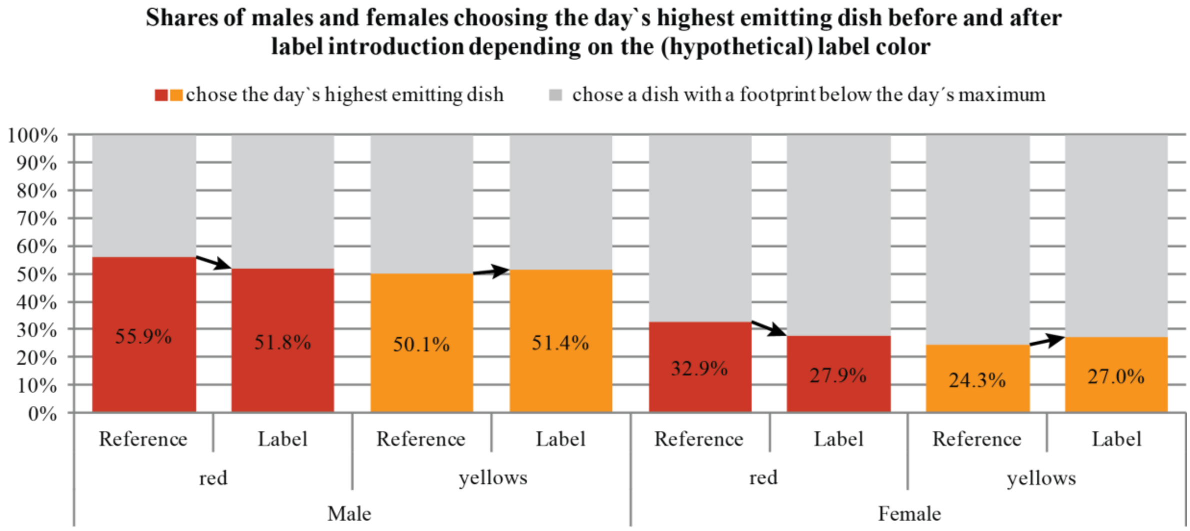

Figure 15: Shares of males and females choosing the day´s highest emitting dish before and after label introduction, depending on the (hypothetical) label color.

6.3.3 Age

From the comparison among age groups, as in Figure 16, it can be observed, that in general there is a tendency towards less emission intensive diets with increasing age. This can be explained by a clearly visibly pattern of decreasing shares in meat consumption with increasing age, replaced by increasing shares in fish and seafood as well as to a smaller extent vegetarian choices (see Appendix Figure 9, p.58). This general pattern was consistent before and after label introduction.

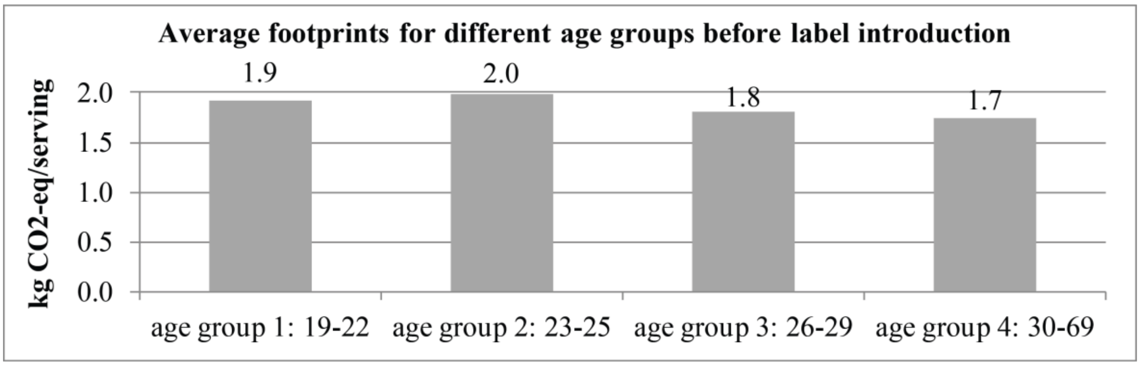

Figure 16: Comparison of average footprint per serving for different age groups before introduction of the label.

Regarding the label effect however, no robust results could be observed. Table 7 gives an overview of the average emission reduction for each age group and their standard deviation. The values are too scattered around the mean to conclude on effects.

	Arithmetic mean of daily emission reduction/serving	Standard deviation of arithmetic mean
age group 1: 19-22	-4.05%	14.42%
age group 2: 23-25	-3.03%	13.59%
age group 3: 26-29	-0.52%	11.65%
age group 4: 30-69	-2.76%	12.58%

Table 7: Arithmetic mean of daily emission reduction per serving and standard deviation of arithmetic mean for the different age groups.

6.3.4 Dietary habit

When it comes to the four defined groups of dietary habits, it is not surprising that the general picture prior to the label shows the highest footprints for carnivores, followed by meat&fish, mixed and peso-vegetarians. The latter were found to have only roughly a quarter of the carnivores´, and therefore by far the lowest emissions per serving.

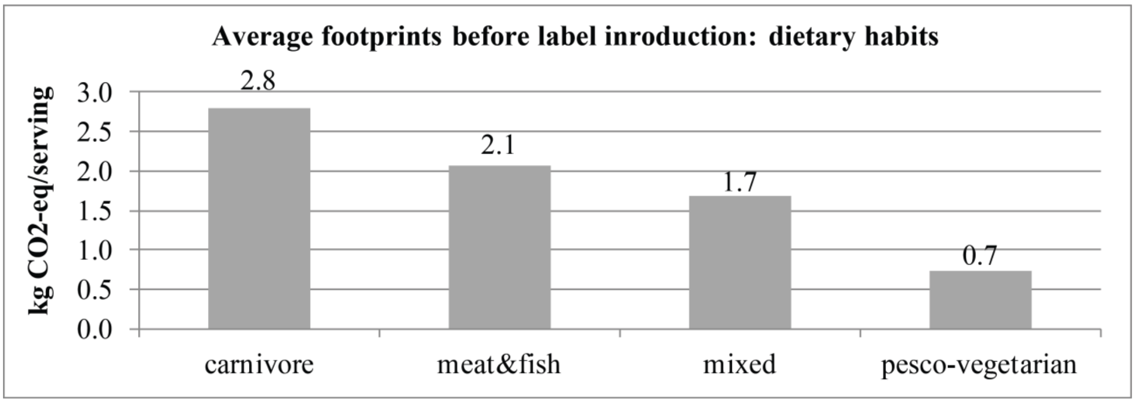

Figure 17: Comparison of average footprint per serving for different groups of dietary habit.

Regarding consumer reaction to the footprint label among people with different dietary habits no definite results could be seen, as shown in Table 8. Additionally it has to be noted for the groups of carnivores and pesco-vegetarians that the sample sizes are rather small, counting less than 70 people who were found to follow these habits and return frequently, both during reference and label phase.

	Arithmetic mean of daily emission reduction/serving	Standard deviation of arithmetic mean
carnivore	-11.86%	12.31%
meat&fish	-0.52%	10.32%
mixed	0.82%	9.10%
pesco-vegetarian	32.29%	58.82%

Table 8: Arithmetic mean of daily emission reduction per serving and standard deviation of arithmetic mean for the different groups of dietary habits.

6.4 Patterns in taste preferences

Aside of carbon footprint information, another factor known to strongly play into consumers´ food choices are preferences in taste. These are individual, dynamic over time and with changing combinations of choices. On an aggregate level however, some clear patterns of outstandingly popular and unpopular food, are visible. Appendix Table 2 p. 57, gives an overview of particularly popular and unpopular vegetarian, fish and meat choices, including exemplary dishes. It was found that especially well selling dishes can be summarized in four categories: *World Food*, *Fast Food Style*, *Mediterranean Classics* and *Local Classics*. Thereby World Food comprises firstly the Asian cuisine, in particular Southeast Asian and Indian food such as currys and woks; and secondly the Latin American cuisine, particularly Mexican street food style as for example tortilla bread with guacamole. Similarly the typical (American) fast food style, such as burgers, pulled meat with potato wedges or French fries etc. attracts many. Mediterranean Classics include mostly typical Italian and French dishes, e.g. lasagna, risotto and ratatouille. Worth mentioning at this point is that all kind of vegetarian lasagna were found particularly popular vegetarian choices. Local Swedish classics are for example dishes with meatballs (and lingonberries), salmon or Västerbotten cheese. The latter two are rather expensive ingredients, which might induce a high perceived value-for-money ratio and thereby additionally promote sales. The same may be true for more expensive beef cuts, e.g. entrecôte or chuck roll, which equally reach high sales shares.

When it comes to meat dishes it turns out that there is a wide variety of non-ruminant, and hence lower emitting options which are perceived as highly attractive. This is true for both, pork and poultry (Appendix Table 2, p. 61). Kårrestaurangen offers two meat alternatives every day, Classic Meat and Classic Meat Salad. It can therefore be assumed that these function as substitutes to each other for people following a predominantly carnivorous diet. This means, that within the given menu there is potential to steer choices away from beef and lamb by parallel offering attractive substitutes. Currently this potential has not yet been tapped, as often times it is meat originating from the same animal in both options. Three selected examples for days with an attractive low(er) emitting meat alternative to beef or lamb are analyzed in Table 9.

Overall the observations regarding taste preferences show on the one hand, that taste plays a stronger role in food choice than carbon label information. As can be seen in Table 9, at row 19.05.2016, where particularly high footprints are disregarded in favor of preferred taste. On the other hand, attractive alternatives to high emitting dishes can support low emitting choices, e.g. Table 7, at row 18.04.2016.

	Classic Meat	kg CO_2-eq	sales share Classic Meat	Classic Salad Meat	kg CO_2-eq	sales share Classic Salad	thereof Classic Salad Meat	sales share Classic Salad Meat
historic average shares			**49.77%**			**9.45%**	**38,27%**	**3.62%**
19.05.2016	Baked chuck roll, rosemary sauce & garlic roasted potato wedges	**9.0**	59.15%	Roast beef & potato salad	**5.6**	8.72%	14.06%	1.23%
	Beef to beef substitution. Taste preference for the more exclusive beef cut with a footprint of 9 kg CO_2-eq seems to counter substitution to lower footprint beef dish.							
18.04.2016	Swedish hash, fried egg & pickled beetroots	**15.1**	29.46%	Deep fried chicken & pepper dip	**0.5**	26.91%	58.95%	15.86%
	Beef to chicken substitution. Extremely high footprint (15 kg CO_2-eq) for beef, which has shown to be unpopular already during reference phase, therefore high substitution towards the popular chicken option. Taste preferences support label.							
10.05.2016	Fried streaky bacon, onion sauce or brown beans, boiled potatoes	**1.3**	31.29%	Chuck roll stuffed bell pepper, buck wheat & pepper dressing	**4.3**	17.25%	35.90%	6.19%
	Pork to beef substitution. The lower emitting pork dish has repeatedly shown to be unpopular in taste, while the meat salad is an attractive beef dish. Therefore taste preferences counteract the label.							

Table 9: Analysis of three examples for days during label phase with an attractive lower emitting meat alternative to beef or lamb. Note that the colors represent the label color of the respective dish.

7 DISCUSSION

7.1 Limitations of the Label Design

A critical point when it comes to the label design are the underlying life cycle data. The emission data used in this study are rather highly aggregated, using averages for groups of ingredients. Currently data are not widely available at a more refined level, which is due to the high cost as well as methodological uncertainties of LCA studies. This required me to make assumptions, e.g. that all fish would originate from Norway and is transported via truck directly to Gothenburg. These approximations are only limitedly accurate. For many ingredients, especially those with generally low emission levels, this is unlikely to influence the overall emissions of a meal to an extent that would alter the label. For other products, however, large differences can be expected from one supply chain or producer to another, or even for one and the same supply chain over time.

A higher degree of precision was found particularly desirable within the group of ruminant products. The highest emitting dish served during the experiment was labeled responsible for more than 15 kg of CO_2-eq because its main ingredient was beef procured from Latin America. According to the chef, this would not give a fair picture though, because the used type of meat was a cut of minor quality resulting as by-product or often even waste from other cuts and can therefore not be allocated the same emissions as for example fillet. Indeed, it has to be acknowledged that taking differences between different meat cuts into account, may have lead to substantially different label values and hence potentially different consumer reactions. To date however, emission data for different meat cuts are not readily available. The very few studies making a first attempt in this direction (e.g. Scholz, 2013; Stucki and Eymann, 2015) seem to agree on the use of economic impact allocation, but not on how a cattle is divided into different cuts neither on what is considered a cut (e.g. chuck roll) versus a final product (e.g. sausage) or a way of preparation (e.g. schnitzel). Cuts as well as prices vary between markets and areas, and can thus not be applied universally, which makes it a complex issue. Within the given time frame of this study it therefore had to be neglected, clearly posing a limitation to the label design.

7.2 Limitations of the label implementation

The practical implementation of the label in running operations was in so far challenging as that it turned out to be a time consuming task for the chef, additionally to the running operations. The manual documentation of the ingredients alone, hence disregarding time and effort that went into the initial label launch, took about two hours per week. This raises an interesting question for further investigations regarding the cost effectiveness of such labeling schemes.

A more sophisticated software solution, e.g. in the form of a mobile application, could perhaps facilitate the operations of the labeling scheme and minimize the required time. Nonetheless, such an application would need to be equally customized to the environment of the specific restaurant and work hours saved would oppose investment cost for the software.

Moreover, such an application could ideally be connected to a food data base, which can offer continuously updated and much more detailed emissions data, than was the case in this study. In recent years several multi-stakeholder initiatives to establish such databases could be seen, for example the World Food LCA Database (available at: http://www.quantis-intl.com/microsites/wfldb/datasets.php, last accessed July 2016).

Regardless of the above, a restaurant could take further actions along with the implementation of a labeling initiative to increase the effect. For research purposes of this study I refrained from measures such as the following: The menu can support the label by offering tasty alternatives to high emitting options; meal-pricing can be used to give incentives, product procurement can be changed, e.g. local beef instead of Latin American beef offered at higher prices reflecting the higher cost; guests could receive feedback on their individual and/or collective emission scores; and quizzes with questions on food sustainability could win guests free meals. Some of these could even be implemented without additional cost.

All in all, there is potential to further improve the possibilities for restaurants to implement carbon labels.

7.3 Limitations of the analysis

Ultimately the goal of a carbon label is to reduce greenhouse gas emissions. To examine this effect, as mentioned before, is more complex than comparing the cumulative footprint of purchases before and after the label introduction. A number of indirect effects may potentially influence actual outcomes. These effects, however, are hard to capture and beyond the scope of this study.

Indirect effects: consumer side

On the consumer side increased awareness and knowledge may spillover to consumption beyond the labeled products. In the particular case of this study, students might apply the information also to their shopping and cooking habits outside campus. In contrast a rebound effect (Hertwich, 2005) may diminish the climate friendly choice at canteen lunch. This may for instance be the case when guest perceive their abstinence from a high emitting dish at lunch an alleviation of their personal emission budget and in turn the license to choose more emitting at the next meal, perhaps outside the labeling scheme, e.g. at dinner. Up to date these indirect consumer effects are not yet researched for the specific case of carbon product labels.

Indirect effects: supply side

Furthermore, changes on the restaurant´s supply side, may on the long term lead to improvements in menu-planning and procurement as a result of internal learning. These indirect label effects, gradually fostering more sustainable supply chains, are often considered the true value of carbon labeling (Upham, et al. , 2010; Larsson and Khan, 2011; The Economist, 2011; Quinteiro et al., 2014). This is because changes on the supply side are likely to have higher leverage effects than behavioral change of single consumers. However, to date this hypothesis lacks proof through scientific evidence and therefore requires further research. In the case of Kårrestaurangen the kitchen staff was purposefully asked not to make any changes internally for the time of the ongoing research. However, learning from the label stimulated intentions to do so in the future.

7.4 Uncertainties of the results

A main aim of this study was to research the label´s effect on GHG emissions. However, the results generated from the collected data fail to answer whether or not the label had an effect and consequently how big such an effect may be. The results indicate a small signal compared to high uncertainties. A mayor problem is the strong influence of aspects such as taste preferences on people´s choices. These could not be adequately isolated because of insufficient control data. Moreover, disturbances due to gaps in the electronically collected data, for salads and classic meat choices, could not be entirely compensated by additionally collecting data manually.

7.5 Recommendations for future research

This leads me to some reflections on what I would approach differently if I were to repeat the experiment. The problem of poor control data could be overcome by repeating the dishes offered prior to the label in the same combination and sequence after introduction of the label. Alternatively a control restaurant with identical choices and conditions could be run in parallel. Additionally, longer observation phases could improve the data quality. These aspects can be seen as general recommendations for similar studies in the future.

Beyond researching the effect of a carbon footprint label on consumer behavior and eventually on GHG emissions, it would be interesting to study how menu planning according to emissions and taste preferences can support emission reductions.

Apart from that, what would be an interesting subject for future research is the supply side effects of carbon labels. To my knowledge the common claim of supply chain effects outweighing consumer effects is not yet supported by evidence form quantitative investigations.

Further effort would also be much appreciated in establishing LCA databases on food products and making them accessible for private, public and research initiatives. Thereby also specific cases such as emission allocation between different meat cuts may be addressed.

8 CONCLUSIONS

In this section the three initially raised research questions regarding label design, label implementation and label effects shall be answered. Reflecting on the aim of the study, conclusions will be drawn on results and potentials for further improvement of carbon labeling schemes.

Label Design

When it comes to label design a number of generally applicable criteria could be defined (see

Table 4). These are ideally adjusted to the specific circumstances of the individual restaurant. Besides it can be concluded that carbon product footprints are dynamically changing metrics which are currently captured with limited accuracy only. It is therefore desirable to connect carbon labels to footprint databases which cover a wide product range and are continuously updated.

Label Implementation

The implementation and operation of a carbon labeling scheme to the existing routines of a restaurant requires quite some effort and time to be invested. This could potentially be facilitated via software solutions and the connection to food LCA databases. Moreover, a climate label may be accompanied and supported by a number of additional measures.

Label Effect

The uncertainties in the collected data are too high to draw conclusions on whether the label had an effect or not. Hence the third research question regarding the label effect cannot be answered. A control phase or control restaurant with identical offer as during the treatment phase or longer periods of data collection would be required to eliminate these uncertainties.

Given the strong influence of taste preferences, however, and looking at patterns in these preferences it turns out that there is untapped steering potential towards more climate friendly consumption on the supplier side, i.e. in hands of the kitchen. The results suggest that considering both, preferred tastes and emissions, in a restaurant´s menu planning makes a promising case for emission reduction.

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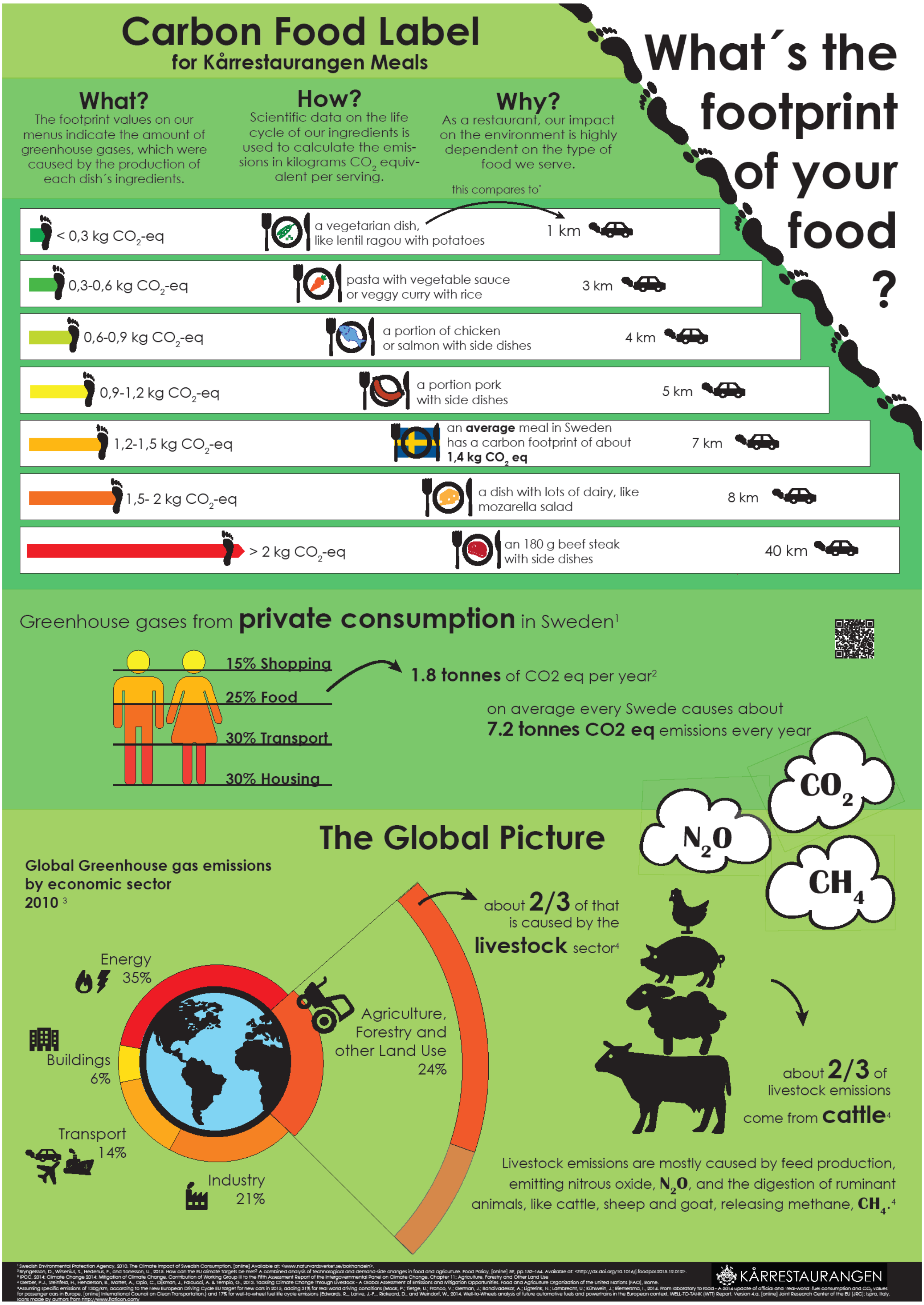
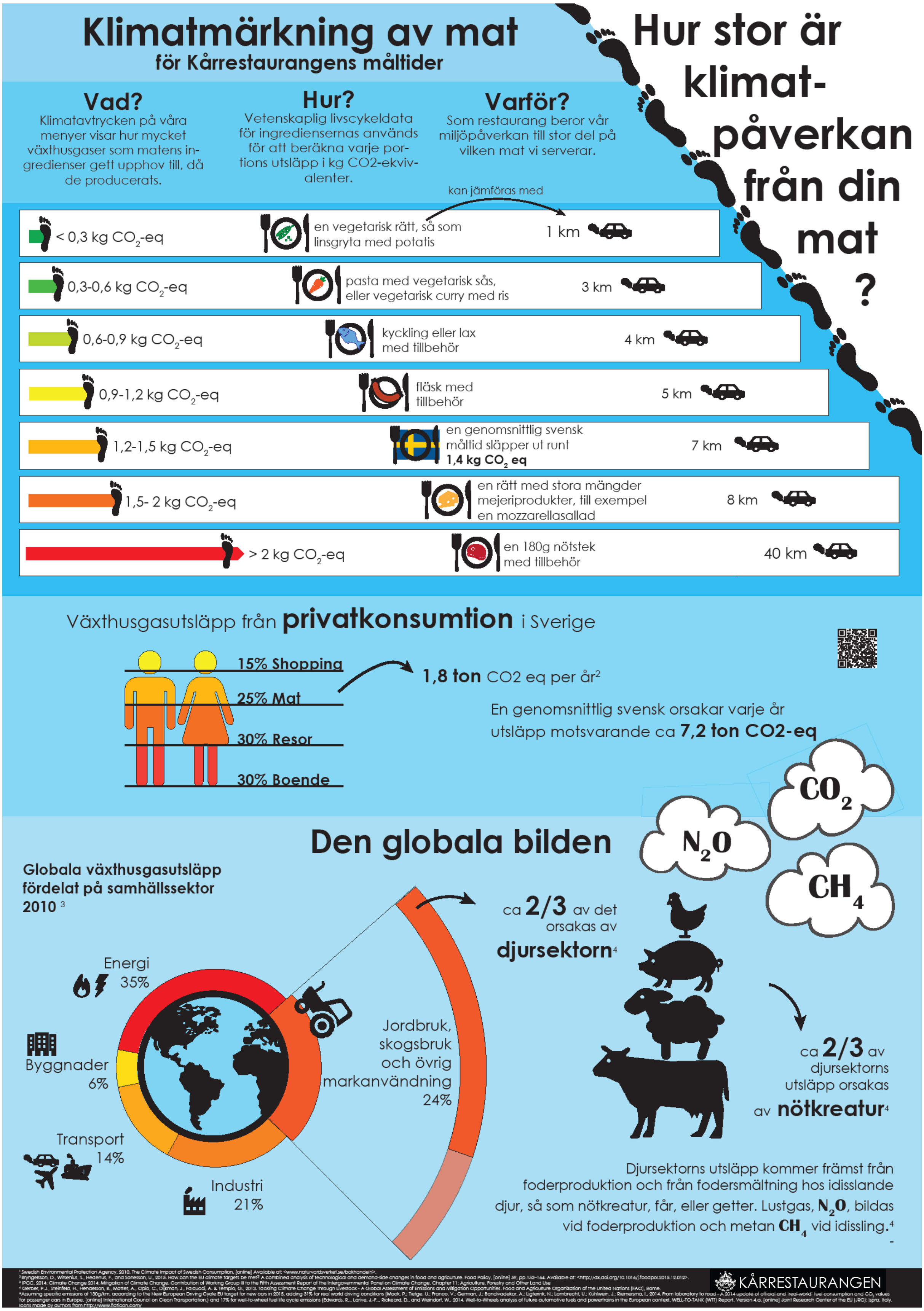
APPENDIX

1. Posters

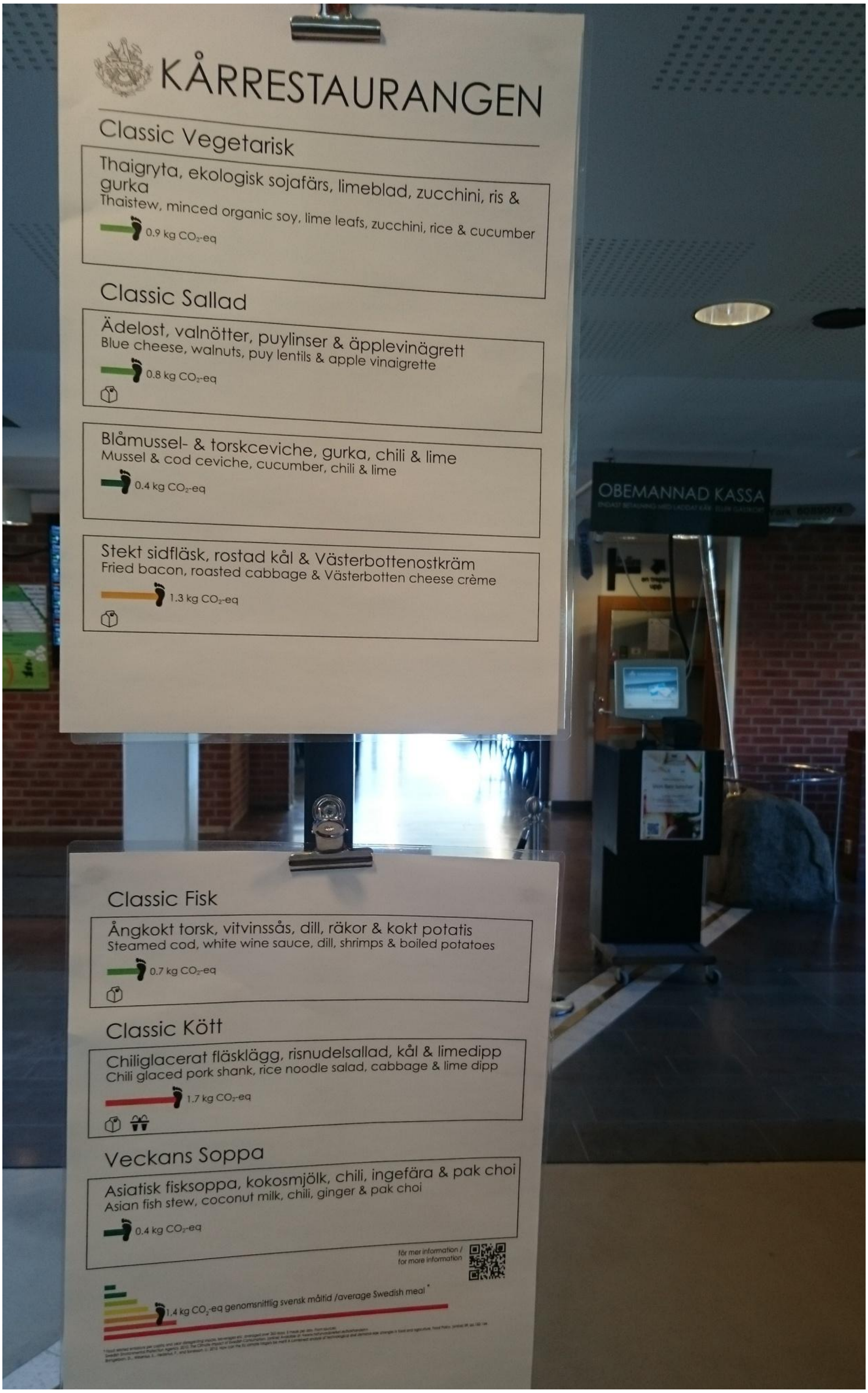


Appendix Figure 1: Poster with additional information in English.

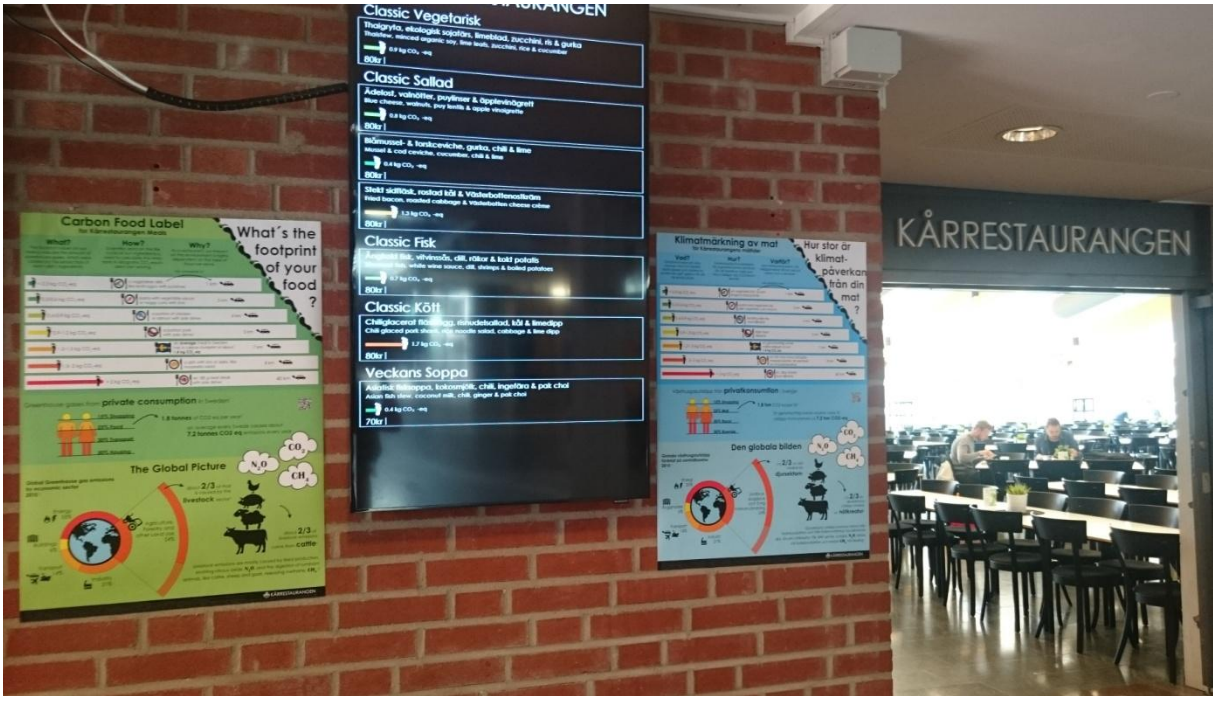


Appendix Figure 2: Poster with additional Information in Swedish.

2. Photos of experimental set-up



Appendix Figure 3: Photo of the print menu in front of the restaurant entrance.



Appendix Figure 4: Photo of the screen menu and information posters in front of the restaurant entrance.

Appendix Figure 5: Photo of the folders standing on lunch tables in the restaurant, front.

Appendix Figure 6: Photo of the folder standing on tables in the restaurant, back.

3. Webpage

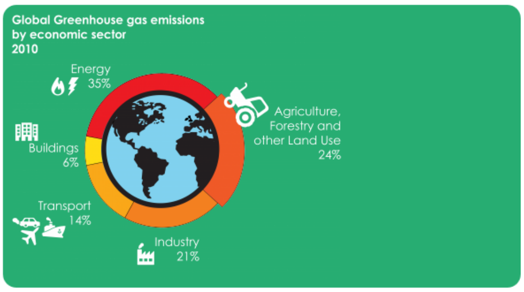
Conference ⌄ Event Restaurang/Café ⌄ Catering ⌄ About us ⌄ Guest/Student card ⌄ Lunch menus ⌄ Language: ⌄

CARBON FOOTPRINT – FOR THE LUNCH MEALS AT KÅRRESTAURANGEN

When it comes to environmental sustainability our impact as a company, in the restaurant and catering sector, is to a great extent determined by the choice of which food to procure and serve to our guests.

THE CURRENT GLOBAL PICTURE

Modern agricultural systems are cause to multiple environmental problems from local to global scale, such as deforestation, loss of habitat, biodiversity and other ecosystem services, soil erosion, disruption of nutrient cycles and emissions of greenhouse gasses (GHG). About a quarter of mankind´s worldwide GHG emissions stem from the agriculture, forestry and land-use sector.



However, when it comes to emissions, there are large differences between food products and their origin. The livestock sector alone is responsible for 14,5% of all global GHG emissions.[1] This means almost two thirds and hence the majority of all agricultural emissions results from the production of animal based products like meat, egg and dairy.

Meat and dairy products from cattle are the largest (GHG?) emitters. This is for two reasons: firstly, meat and dairy have a very low energy conversion efficiency, due to large areas of land required for growing feed used in raising livestock. The second factor is the way cattle digest their feed. Like buffalo, sheep and goats, cattle are ruminant animals; when chewing and fermenting their feed some of the carbon is converted into methane, CH_4, which is released to the atmosphere. CH_4 is a (34 times) more potent greenhouse gas than carbon dioxide CO_2.

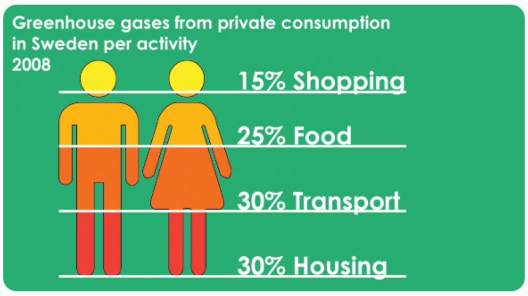
THE GLOBAL FUTURE

Climate change and the cuts in emissions required to limit global average temperature increase to below 2°C compared to pre-industrial levels, as agreed by 195 nations at the UNFCCC Climate Conference in Paris in December 2015[1], poses a major challenge to all economic sectors. While GHG emissions have to be reduced, the livestock sector is at the same time facing a significant rise in demand, due to the growing world population and increasing wealth.

Recently published research points out that it will not be enough to reduce greenhouse gas emissions from the combustion of fossil fuels in the energy system. Thus, it is imperative to also reduce emissions of nitrous oxide and methane from agriculture. [1],[2] Increased productivity, technological advancements and reduced food wastage contribute to emission reductions , however, it will also require dietary changes , for example in the form of reduced consumption of beef and dairy products.

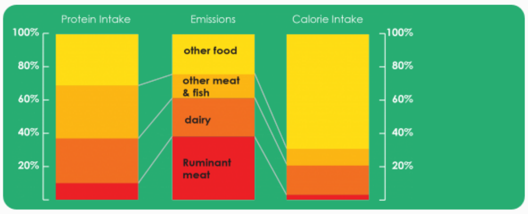
THE SWEDISH CONSUMER PERSPECTIVE

From the perspective of an individual living in Sweden, on average one quarter of emissions which are directly or indirectly caused by private consumption stem from food.



Source: European Commission, 2016. EC Climate Action. [online] Available at: this URL [Accessed 22 Mar. 2016].

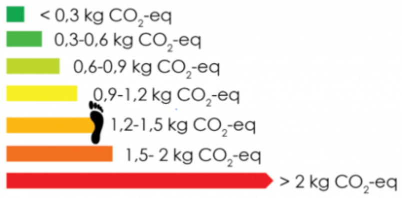
Over the course of one year, this equals approximately 1.8 tonnes of CO2-eq, of which 38 % are from ruminant meat and 23% from dairy products.4 Comparing this to people´s energy and protein consumption, however, only small shares are covered by beef and dairy respectively, as shown in the following graph.



In total every Swede emits an average of about 7.2 tonnes CO2-eq per year. Note that this is private consumption only, and does not include emissions from the public sector. [5]

THE CARBON FOOTPRINT LABEL

Being aware of the climate issues related to food, we decided to assess the carbon footprints of meals on campus. Starting in our biggest restaurant, Karrestaurangen at Johanneberg Campus, we introduced carbon labeling to the menus. It is a way for us to learn , and at the same time an opportunity to share information about the food's climate impact with our guests. The traffic-light-colored bars shall allow easy distinction between low and high footprints and comparison among the different dishes.



The values right to the colored bars and footprint symbols express the approximate amount of greenhouse gases emitted per serving.

HOW IS THIS VALUE CALCULATED?

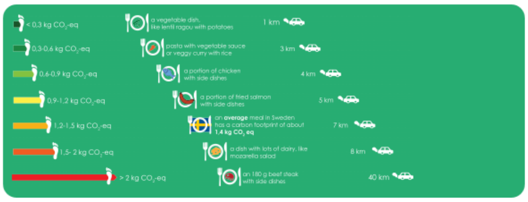
Our chefs know how much of each ingredient they use to prepare your lunch. These ingredients are listed in different product groups. For each product group, the respective quantities are combined with scientific data on life cycle emissions, adding up to the footprint per dish.

WHAT DOES THE FOOTPRINT INCLUDE AND WHAT NOT?

The resolution of available data from life cycle assessments is limited due to the complexity of the method.The data underlying this label is therefore aggregated to average emission values for groups of food products consumed in Sweden. For example one kilogram of pasta sold in Sweden has an average footprint of 0.6 kg CO2.4 Distinctions between different producers and product types like whole grain pasta, conventional or organic are not made. The footprint includes direct emissions resulting from the consecutive production stages along the supply chain. Additionally indirect emissions related to these processes are included, such as fertilizer production or power generation. Both, direct and indirect emissions are expressed in kilograms of carbon dioxide equivalent (CO2-eq), that is both, CO2 itself, but also other climate relevant gases, like methane (CH4) and nitrous oxide (N2O). Not included in the footprint label, due to their minor contribution, are life cycle stages at the sales level, such as transportation to our restaurant, preparation of the food and management of food waste.

HOW MUCH IS 1 KG OF CO2 EQUIVALENT?

Thetraffic- light colors from green (low emissions) to red (hihg emissions) and the length of bars according to the footprint indicate what is a relatively better or worse choice for the climate. In absolute terms, however, the emission values may be harder to interpret. How much is a lot or a little and how does this compare to other emission sources in our life? Food products are not commonly associated with emissions, such as driving a car, i.e. car-emissions seem to be much more concrete than emissions from production processes with many steps. So how many kilometers could you drive, causing an equal amount of emissions as your lunch? We calculated some examples below:



How were the emissions translated into car kilometers? Assuming specific emissions of 130g/km under test conditions(according to the New European Driving Cycle EU target for new cars in 2015 plus 31% to compensate for real world driving conditions[1] and another 17% for well-to-wheel fuel life cycle emissions[2], gives roughly 200 g CO2-eq per km driven.

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[2] European Commission, 2016. EC Climate Action. [online] Available at: [Accessed 22 Mar. 2016].

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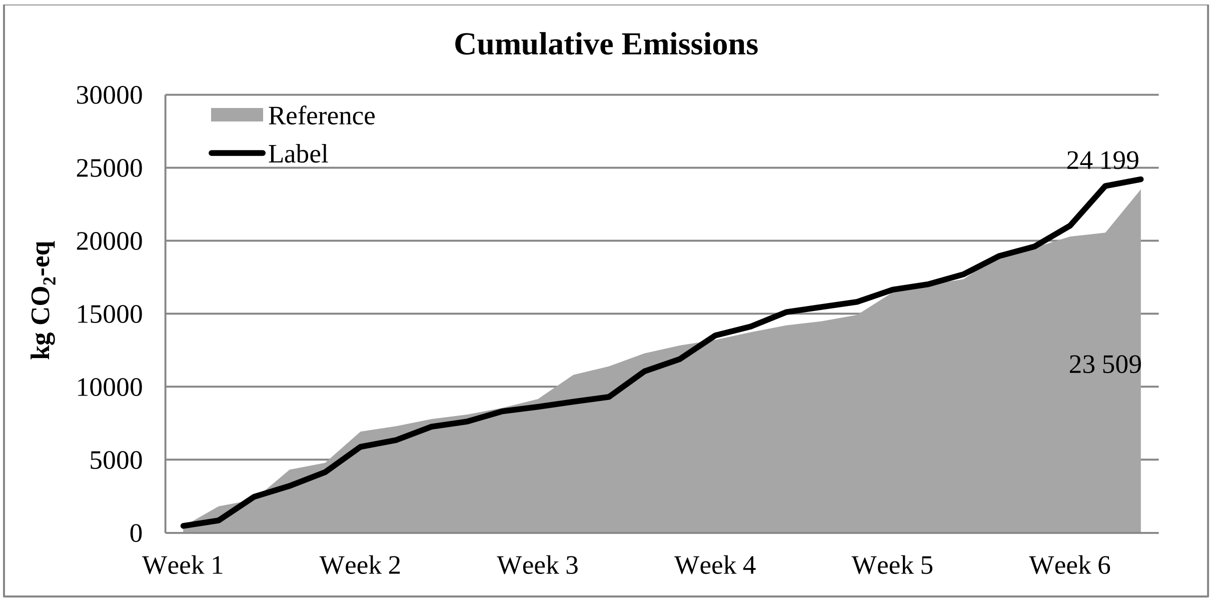
Appendix Figure 7: Information presented at the webpage of the restaurant company.

4. Table: Historic sales shares of product groups

Product Category	Historic sales share
Classic Meat	49.77%
Classic Fish	26.47%
Classic Vegetarian	11.15%
Classic Salad	9.45%
thereof meat salad	38.27%
thereof fish salad	25.21%
thereof vegetarian salad	36.52%
Week´s soup	3.16%

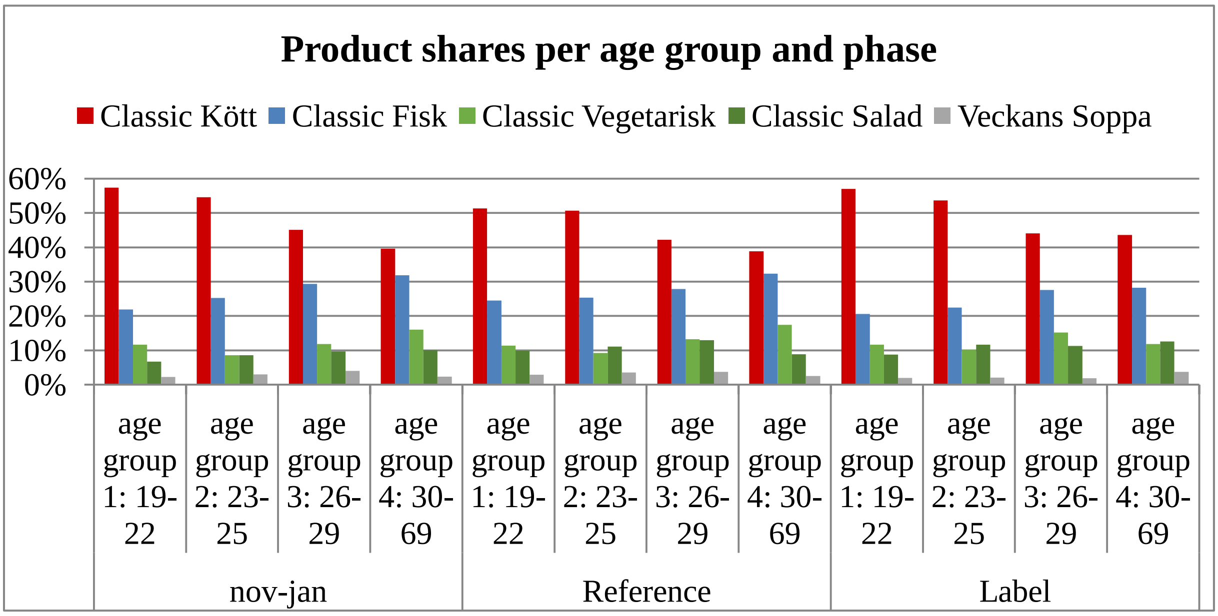
Appendix Table 1: Historic sales shares of the daily offered choices before label introduction. The underlying data includes consumption from November 2015 to March 2016.

5. Figure: Cumulative emissions



Appendix Figure 8: Total cumulative emissions from all meals consumed by students at Kårrestaurangen during reference and label phase. Note that this is absolute values and differences in emission intensity of the offer is not controlled for here.

6. Figure: Product shares age groups



Appendix Figure 9: Product shares per age group and phase. Note that the phase Nov-Jan represents historic consumption data from November 2015 to January 2016, before project start.

7. Table: Patterns in taste preferences

	Category	Specification	Example
Especially popular vegetarian food	Vegetarian Patties	Vegetable patties	Squash & brown rice pattie, tzatsiki, olive cous-cous & roasted mushroom
	Asian Cuisine	Southeast Asian, Thai, Indian, especially Currys	Pad thai, minced soy, rice noodles, roasted cashew nuts & lime Korma, indian curry, cauliflower, mushroom, red lentils, rice & mango chutney Nasi goreng, tofu, vegetables & egg Red curry stew, coconut milk, lemon grass, chickpeas, pepper & jasmin rice
	Latin American Cuisine	Mexican fast food style	Marinated beans, deep fried tortilla bread & guacamole
	Italian Classics	(Vegetarian) Lasagna	Cauliflower & spinach lasagne, roasted cauliflower & rocket salad
		Risotto	Mushroom risotto, fried oyster mushroom & parmesan cheese
		Pasta	Pasta Bolognese (with meat alternative e.g. from soy)
		Tortellini	Spinach & ricotta tortellini, cheese sauce, asparagus & broccoli
	French Classics	Ratatouille	Ratatouille gratin, kidney beans & Feta cheese cream
Especially unpopular vegetarian food	Cliché vegan food	Main ingredients grains like bulgur, quinoa, cous-cous, chickpeas, beans	Chickpeas & cous-cous salad & green pea cream Hirs gratin & roasted garlic cream
	Other	Omelettes	Vegetable omelette
		Eggplant	Aubergine, zucchini & tomato stew, kidney beans, rice & zucchini salad
		(Vegetarian) 'Shepard´s Pie'	"Sheperds pie", peas, tomato, mashed potatoes

Especially Popular Fish & Seafood	Salmon	Fried Salmon	Fried salmon, gremolata, roasted vegetables & roasted garlic cream
		Smoked Salmon	Smoked salmon, steamed broccoli, cider mustard cream & boiled potatoes
	Seafood	Shrimps	Caribbean shrimp salad, mango, melon & lime cream
		Gambas	Garlic- & chili fried wild caught gambas, aioli & tomato salad
Especially Popular Meat Dishes	Fast Food Style	Burgers	Pulled pork burger, pickled red onion, French fries & smoked chili dip
	Asian Cuisine		"Chicken tikka masala", basmati rice & raita
			Vindaloo curry, chicken, jasmine rice & mint yoghurt
	Latin American Cuisine	Mexican	Pulled chicken, tortilla bread & tomato salsa
	Exclusive Beef Cuts	Entrecote, chuck roll, etc.	Rosemary fried entrecôte, fried potatoes, whipped schallot butter & red wine sauce
			Baked chuck roll, rosemary sauce & garlic roasted potato wedges
	Fancy Chicken	Baked, fried or other 'fancy' way of preparation	"Chicken tikka masala", basmati rice & raita
			"Coq-au-vin" red wine marinated chicken, mushroom, onion & potato purée
			Herb fried chicken breast, citrus roasted carrot, onion, potatoes & chili cream
			Piccata chicken, risotto milanese & tomato sauce
			Deep fried chicken & pepper dip
			Cornflakes deep fried chicken, mango & lime dip, roasted potato wedges
			Tarragon baked chicken, ratatouille & roasted potatoes
			Tandoori chicken, raita & basmati rice,
	Fancy Pork		Honey glaced pork loin, baked potatoes, whipped herb butter & corn cob
	Lamb		Greek lamb pattie, rosemary fried potatoes & tzatziki

	Local (Swedish) Classics	Köttbullar (meatballs)	Meatballs, gravy, mashed potatoes & lingonberries
Especially Unpopular Meat dishes	Sausages		Chorizo, mashed potatoes & ajvar yoghurt
			Gratinated pork sausage & mashed potatoes
			Bratwurst, cucumber mayonnaise & mashed potatoes
	Stews		Beef stew, soy, carrot, leeks & rice
			Pork stew, tomato, onion, carrot & rice

Appendix Table 2: Overview of particularly popular and unpopular vegetarian, fish and meat choices, including exemplary dishes