Pioneering Historical LCA - a Perspective on the Development of Personal Carbon Metabolism 1860-2020

Simon Bruhn[a*], Styrmir Gislason[a b], Trine Røgild[c], Matilde Andreasen [a], Frederik Ditlevsen[a], Julie Larsen[a], Nana Sønderholm[a], Morten Birkved[a]
[a] SDU Life Cycle Engineering, Institute for Green Technology, University of Southern Denmark [b] SEGES [c] Danish Technological Institute *simb@igt.sdu.dk

INTRODUCTION

A Danish research project investigates the personal carbon metabolism of Danish urban citizens, and how it developed since "the black transition" with occurred at the industrial revolution almost 200 years ago. The overarching objective is to develop scientifically backed museum exhibitions, which can provide a public debate and perspective on the current green transition. The project is an interdisciplinary collaboration between museums and researchers within both humanities and engineering.

OBJECTIVE

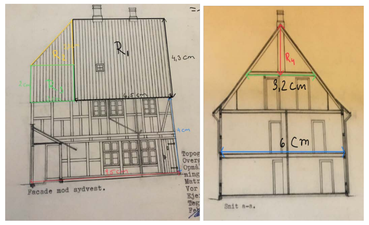
Our role in the project is to explore anthropogenic climate change in a historical perspective, considering the interplay between increased affluence and technological development.
By conducting LCA at five timesteps, a perspective is provided on the personal carbon metabolism and how it has changed during the period 1860-2020.
Five significant consumption segments are included; namely domestic transport, food, housing, furnishing, and residential energy use.

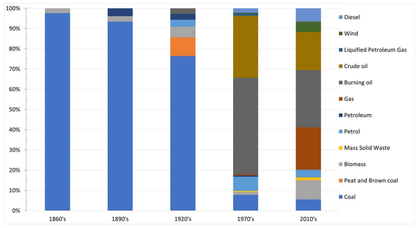
METHODS

The personal carbon metabolism is quantified via historical LCA – an until now unexplored field. This LCA can be considered partially dynamic, and has similarities to the field of prospective LCA. Dynamic elements are implemented in the life cycle inventory, considering changes in consumption as well as technology. Historical data are based on statistics, books, representative case studies, and expert testimonials.

Consumption segment	*Foreground system*	*Background system*
Food	Amount of calories and type of food eaten	Production practices and efficiencies. Energy market mixes and efficiency
Transport	Distance and means of transportation	Infrastructure, entire life cycle of vehicles, occupancy rate and fuel efficiency of vehicles. Energy market mixes and efficiency
Housing	Size and type of housing, number of occupants	Entire life cycle of Materials, construction, and demolition of housing. Energy market mixes and efficiency
Residential energy	Residential energy use	Energy market mixes and efficiency
Furnishing	Amount and type of furniture	Production practices and materials. Energy market mixes and efficiency. Furniture mass

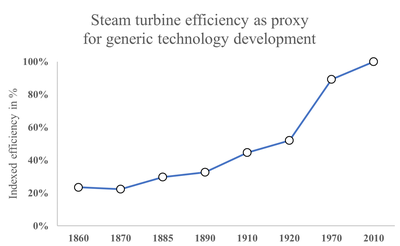
KEY ASSUMPTIONS

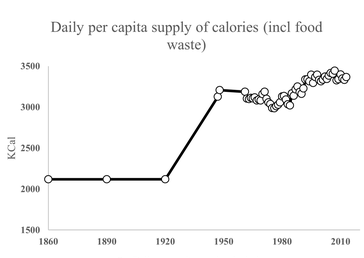




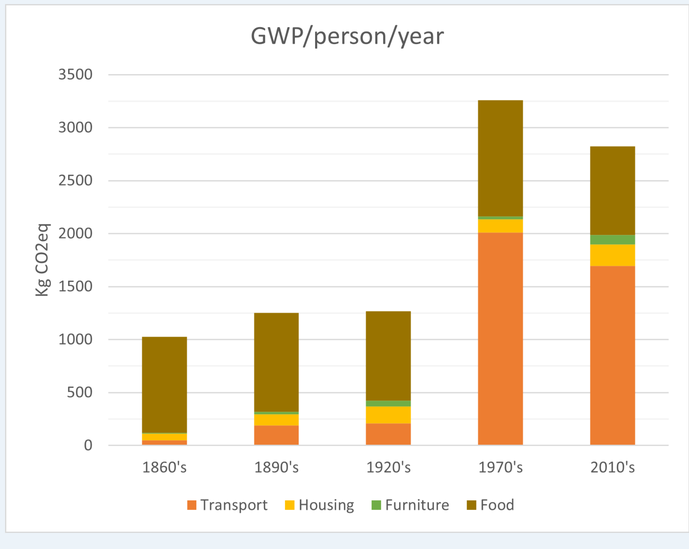
Hundreds of assumptions and estimates have been made. A few examples:

- Primary data from museum buildings (every brick was counted).
- Energy Grid based on national gross energy use accounts.
- Steam turbine as proxy for technological efficiency (correction factor).
- Statistical data on gross calorific food consumption
- Agro-models for direct GHG emissions of foods paired with AgriFootprint and ecoinvent databases

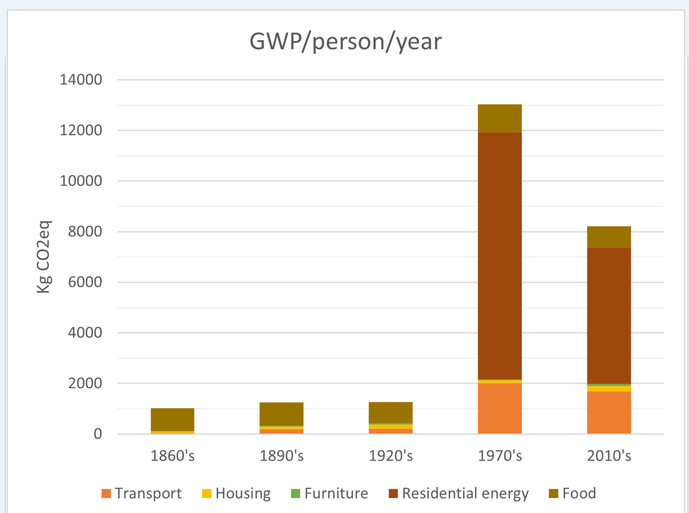




RESULTS



- Prior to the 1920's, the results are near constant. The later years see a significant increase, which historians find realistic and attribute to various historical events.
- In the 1970's and 2010's we find residential energy to account for respectively 75% and 66% of personal carbon metabolism.
- Residential energy statistics not available before 1970's, hence excluded from these graphs. We currently work on proxies for estimating the earlier decades.
- The last century saw to an almost threefold increase, with increased transportation being the main driver.



CONCLUSIONS

Due to the historic nature, data availability is a significant challenge, hence different means to provide a qualified scenarios are explored. The project is ongoing till the autumn of 2023, but current results indicate that the massively increased technological efficiency is not sufficient to keep up with our even more drastically increased affluence. On the brighter side however, the results indicate that the focus on the green transition has led to a decrease in the accelerating growth since the 1970's. The findings of the research is of relevance as it provides a historical perspective on how changes in technology and consumption has affected the impact on climate change, empowering citizens to see the current green transition in this context. In terms of academia, the field of historical LCA is groundbreaking, and has several similarities with prospective LCA, hence it is relevant to discuss with peers at the SETAC meeting.

- Food sector is approximately 24% of Danish GWP according to recent national accounts. We capture half of this through three meals (no snacks or drinks)
- Including residential energy, we find the 2010's result of 8.2 ton CO2eq. The first official consumption-based national account found 10.5 ton CO2eq per person in 2019.
- It is likely that addition of segments such as entertainment, clothing, air travel, etc. would lead us to the official numbers, verifying our methodology.
- Our attempt on historical LCA revealed the massive challenge of collecting and estimating data of high quality and consistency across the time horizon. Eventually, documenting our work as well as ensuring reproducibility is an extensive task.
- Historical LCA, as well as prospective, benefits from scenarios, as they inherently cannot find the true results.
- A study on prospective LCA by the Bruhn et al (2023, in review) stresses the importance of defining consensus-based scenarios. However, most pLCA studies are not well documented and are very difficult to reproduce due to being largely based on expert testimonial and manual (obscure) editing of background systems. Through this historical LCA, we found ourselves falling into these same pitfalls.
- Future attempts on historical LCA will benefit from using computational methods for large-scale modification of background datasets. E.g., changing all electricity providers in ecoinvent to a historically representative dataset.

ACKNOWLEDGEMENTS

We acknowledge all experts, historians, and museums, who have supported us via discussions and assisted our data collection:
Sissel Fossat (Museums of Odense)
Rene Christensen (Denmarks Railway Museum)
Louise Skyggebjerg (Copenhagen Business School)
Dr Maud Launa
Erik Fisker (Old Town of Aarhus)
Bue Poulsen (Aalborg University)
Christina Sørensen (The Energy Museum)
Christian Rasmussen (Old Town of Aarhus)
Jytte Thorndal (The Energy Museum)

The project acknowledges funding from VELUX FOUNDATION grant nr 34214