Workshop N° 16 Data and Models for Quantifying Food supply Carbon emissions

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

Chair : Dr Graciela ALVAREZ INRAE

- Workshop ICR 2023 Data and Models in food supply 24/08/2023

Workshop N° 16 Data and Models for Quantifying Food supply Carbon emissions

AGENDA

11:45h Welcome to the workshop by Graciela ALVAREZ

11:48-11:50 The ENOUGH Project in few words by G. ALVAREZ

11: 50h- 11 :56h Data on quantifying carbon emissions from sectors and food groups within the food chain. Baseline (1990) current (2019) and future (2050) carbon emissions.

By Yosr ALLOUCHE IIR, France

11:56h-12:02h How to reduce carbon emission in supermarkets by using Energy Models .

By Elias EID LSBU UK

12:02h-12:08h The ENOUGH TOOL Simulating energy and CO2 emissions of food supply chains.

By Denis LEDUCQ INRAE, France

12 :08 -12:20h Quantifying Cold Chain Carbon Emissions in USA **Dennis NASUTA**

12:20:12:30 Discussion

THE AIM

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

The project will provide tools and methods to contribute to the **EU Farm to Fork strategy** to achieve climate neutral **food** businesses by 2050

- **Propose strategies to decarbonise** the food chain
- **Integrate and manage** the food chain of the future
- **Demonstrate** new technologies
- **Develop innovative** food chain systemic approaches and solutions

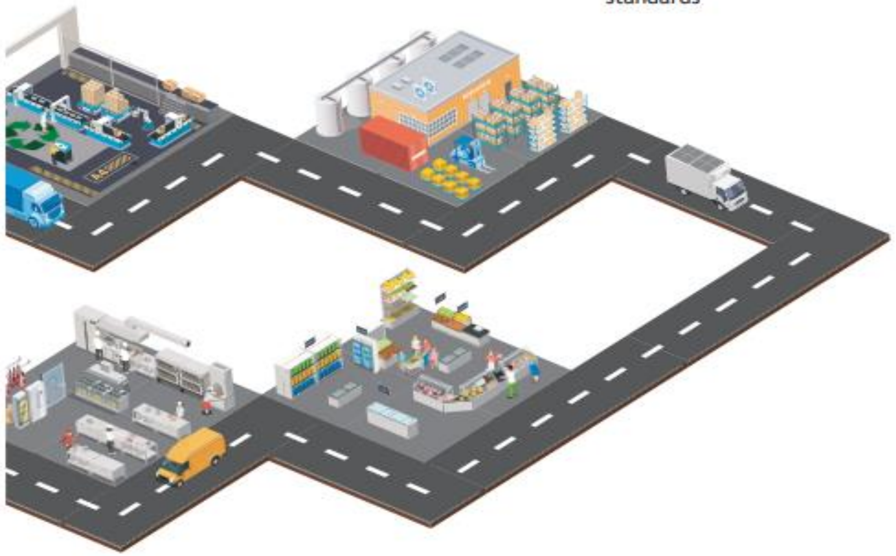
Expected results

What will the ENOUGH project achieve?

- **Provide baseline** food chain emissions for 1990 and 2020 and predict emissions for 2030 and 2050
- **Develop** technology and energy roadmaps of the food supply chain to establish new best practices for each link in the food chain
- **Identify** the greatest potential for carbon reduction
- **Develop, adapt and apply** new technologies to help achieve carbon neutrality for food businesses
- **Integrate** and streamline processes
- **Demonstrate** new technologies to stakeholders
- **Promote** the project findings to stakeholders

What impact will ENOUGH generate?

- **Contribute significantly** to the achievement of the objectives and targets of the Farm to Fork Strategy and The European Green Deal
- **Ensure** a sustainable food supply chain across all sectors of the food chain from harvest/slaughter to the consumer
- **Save** energy and increase energy efficiency in the different sectors of the supply chain
- **Increase** renewable energy use
- **Increase** the adoption of natural refrigerants
- **Prevent** food loss and waste
- **Ensure** food safety and security
- **Ensure** sustainable food consumption
- **Improve** competitiveness and raise standards



Our Partners


Our partners

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EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050
Project period: 2021 - 2025
Project coordinator:
Kristina Norme Widell / Kristina.Widell@sintef.no

SCAN TO VISIT OUR WEBSITE
www.enough-emissions.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101036588

Our coordinator:
Kristina Norme Widell
SINTEF

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EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

Current (2019) and Future (2030 and 2050) of the European Food supply Chain

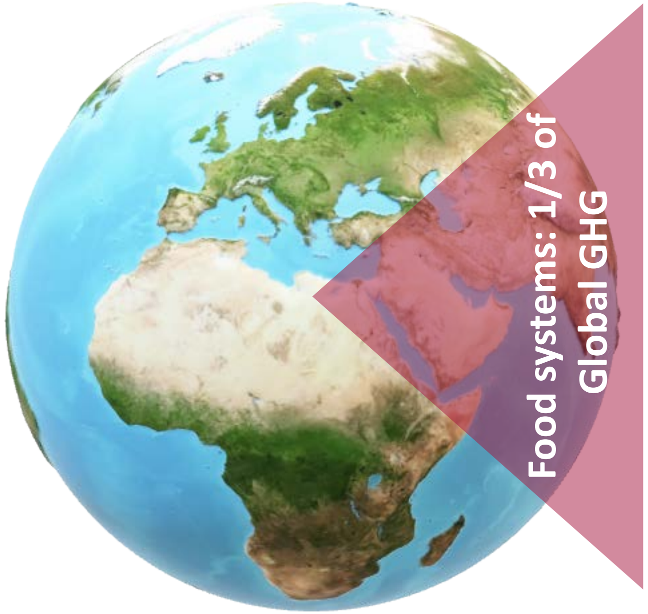
Yosr Allouche , Head of projects

IIR

Data and Models to quantify CO2 Emissions in Cold Chain and Food Systems

THE EUROPEAN FOOD SUPPLY CHAIN EMISSIONS: WHERE TO ACT?

MOTIVATION: Few numbers but huge emissions



- Share in **Total emissions** decreased from 38% (2000) to 31% (2020).
- **2020 Global level**

agrifood systems GHG emissions **16 Gt CO_2eq** (+9% (2000)): ~$^1/_2$ from farm gate, $^1/_3$ from post-farm gate and $^1/_5$ LULUC

2020 Regional level

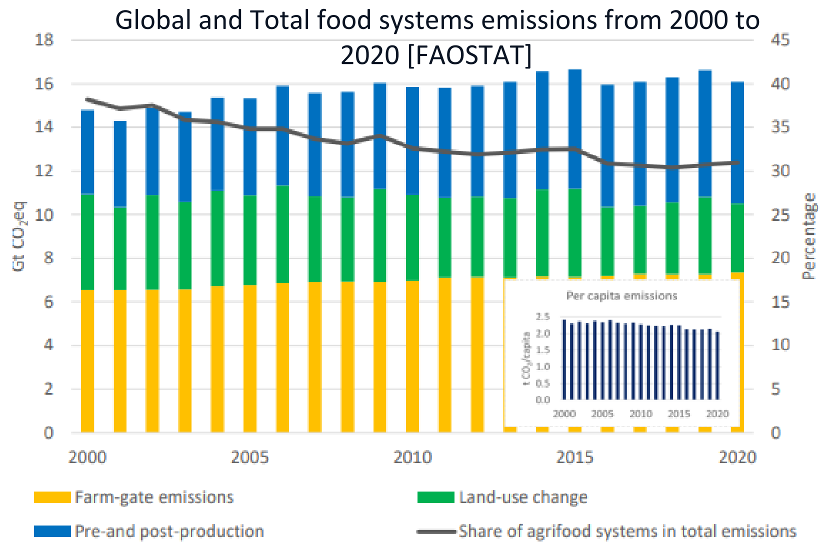
LULUC largest contributor in Africa (44%)

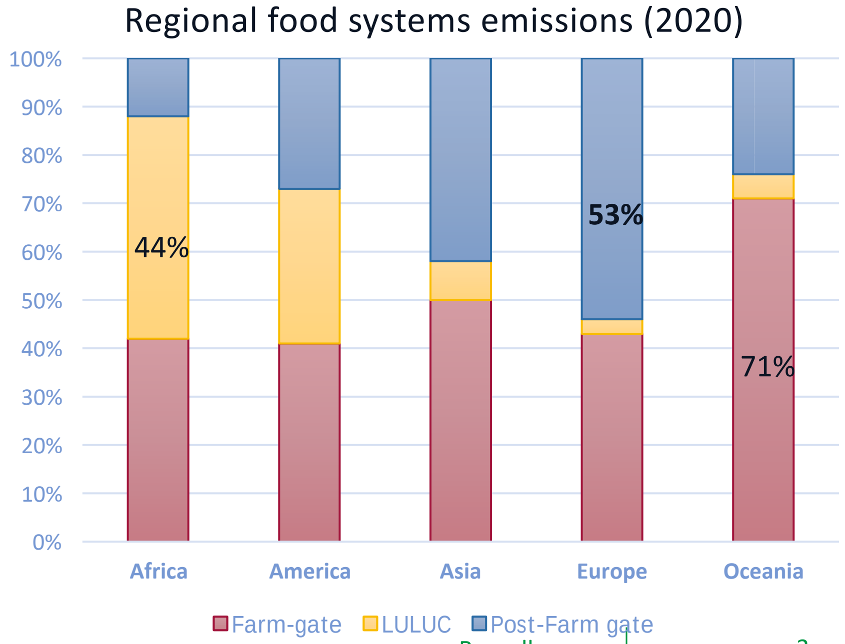
Farm gate dominating in Oceania (71%)

Post-Farm gate largest contributor in Europe (53 %)

Data , Regional and Global emissions graph Source: GHG emissions from agrifood systems: Global, regional and country trends.
FAOSTAT Analytical Brief 50

- WP1 will identify the highest emitting food chain sectors.
- **Innovative Technologies** and **initiatives** for the **food supply chain** to help **decarbonizing** the **2050 food sector.**





OBJECTIVES AND CONTRIBUTING PARTNERS

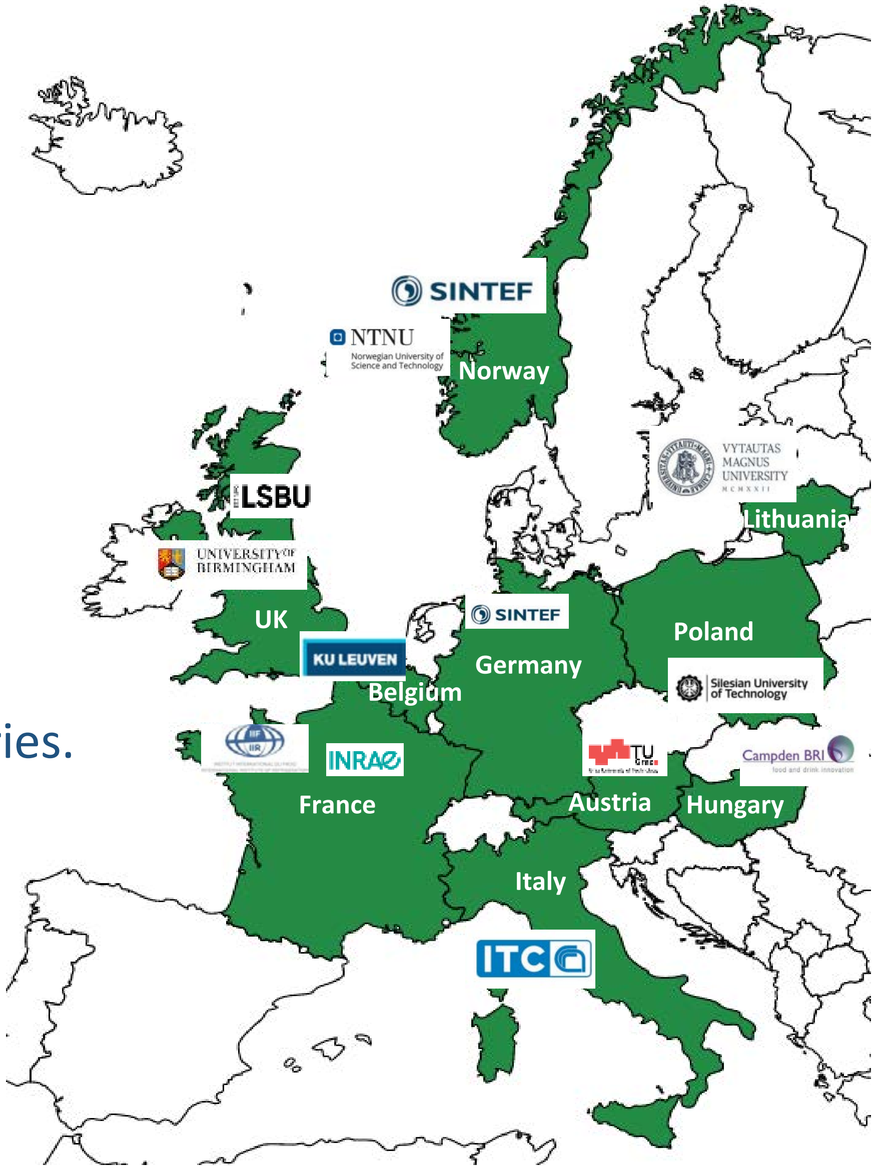
- Mapping emissions from the European food supply chain sectors

(10 countries).

- WP1: baseline (1990), Current (2019) and Future (2030 and 2050) carbon emissions of the European Food supply chain.
- Have a clear and detailed overview about the emissions of all the food chain sectors.
- Identify where data logging is missing.
- A holistic approach to deliver the next generation of the EU food chain:

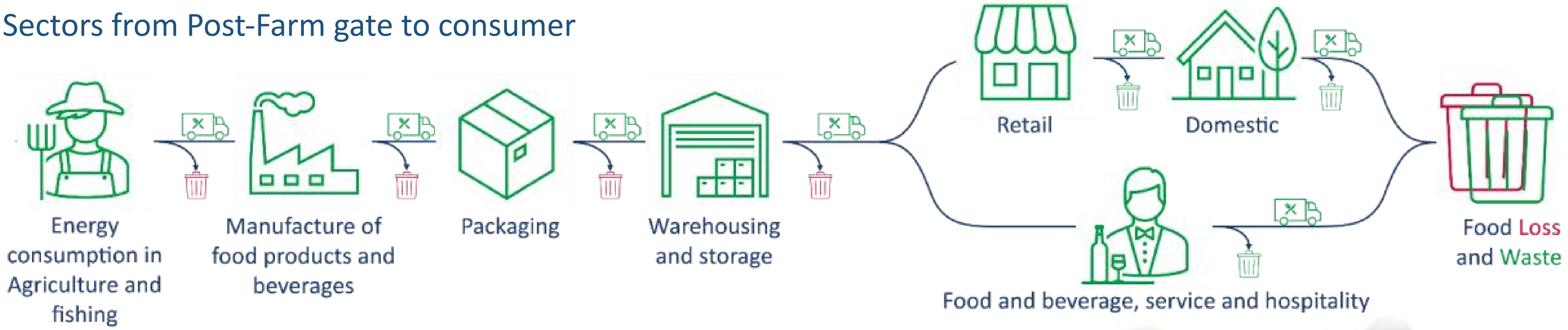
OBJECTIVES AND CONTRIBUTING PARTNERS

- There is notable differences/inconsistencies between the available emissions inventories (FAO, EDGAR..)
- Different methodologies, boundaries and terminology are used
- Limited access/ unavailability of data
- Uncertainty analysis (IPCCC guidelines).
- Sense checked with each other's and compared to other inventories.



TERMINOLOGY AND BOUNDARIES

Sectors from Post-Farm gate to consumer

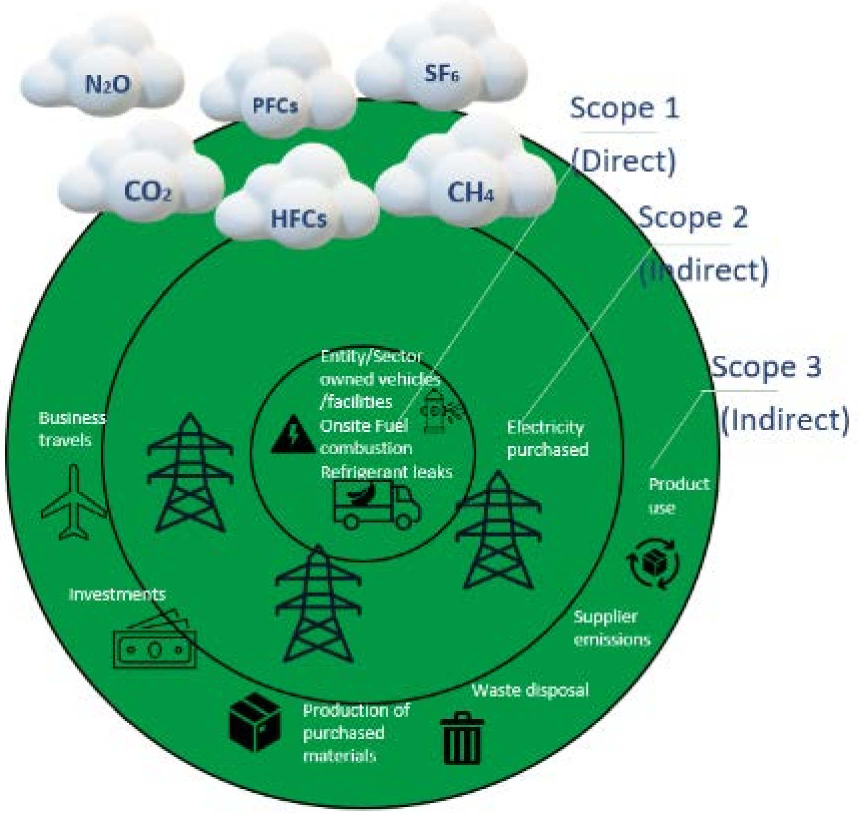


Scope 1 , **Scope 2** and **Scope 3** emissions (GHG Protocol)

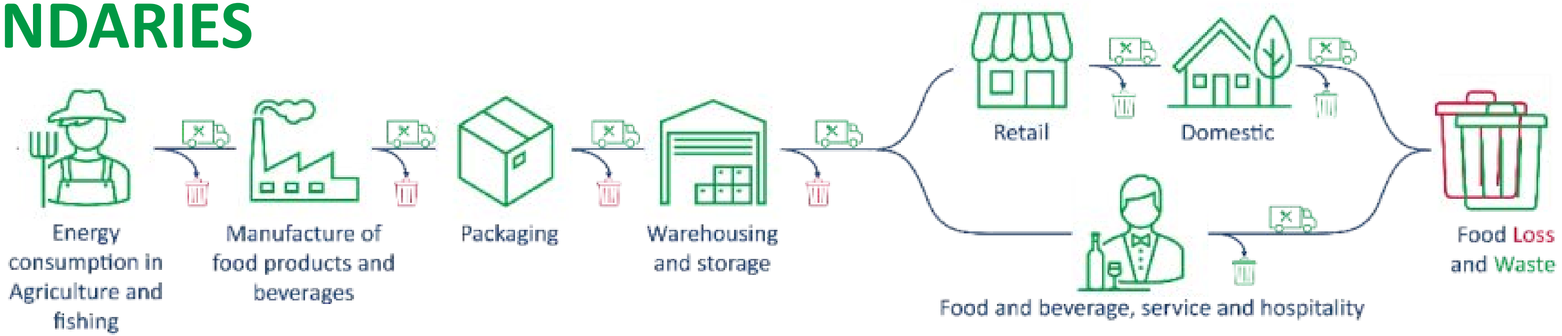
Scope 1 → Onsite fuel combustion for generation of electricity and heat.
Fuel combustion for food transport.
Refrigerant leakage (from filling to disposal)

Scope 2 → Purchased energy, e.g. grid electricity and heat networks.

Scope 3 → Emissions outside of the food sector. We have assumed waste and packaging are important emissions related to the food sector, but outside of the food sector and therefore categorised as a Scope 3 emissions.



TERMINOLOGY AND BOUNDARIES



Geographical boundaries

- Within territorial border
- From farm to fork

Sectors and commodities

- Food and beverages: Perishable (needs refrigeration e.g., meat, fish, dairy, fruits and veg) and non-perishable (canned food, baking, confectionary…), only for human consumption.
- **Agriculture and Fishing**:

Included: On-farm energy use in Agriculture and Fishing (precooling, farm and fishing transport etc)

Excluded Emissions from fertilizers, farm waste, chemicals to land, rumination etc).

- **Manufacture of food products and beverages:**

Included: All Scope 1 and 2.

Excluded Scope 3, except packaging and waste

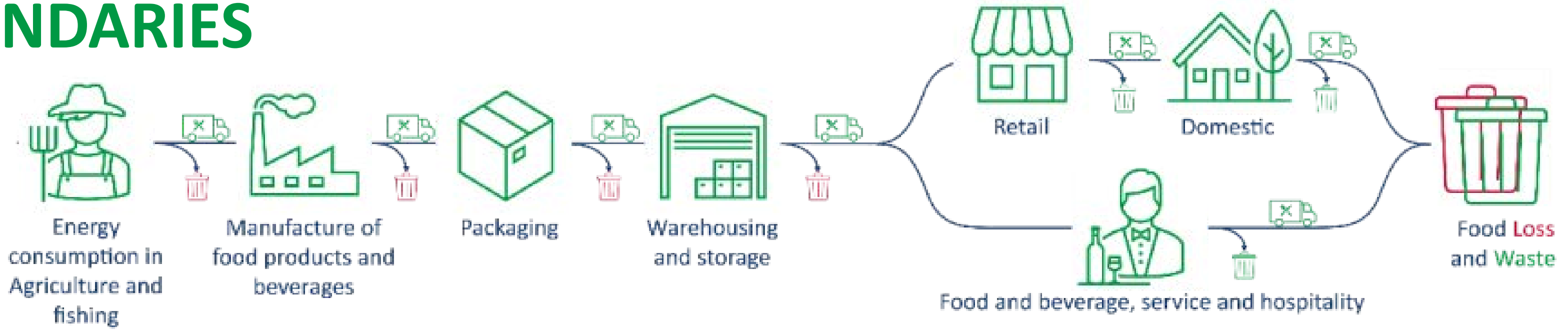
- **Packaging**

Included: Emissions from manufacture of single use packaging materials and manufacturing.

- **Warehousing and Storage**

Included: All Scope 1 and 2 for food based.

TERMINOLOGY AND BOUNDARIES



Geographical boundaries

- Within territorial border
- From farm to fork

Sectors and commodities

- **Transport**

Included: Fuel consumption for refrigerated and non-refrigerated vehicles.
Refrigerant leakage from TRUs.
Domestic transportation and home delivery.
Transport in intermediate country

- **Retail**

Included: All Scope 1 and 2, food based emissions.

- **Service and hospitality** All Scope 1 and 2, food based emissions from restaurants, hospitals, schools etc.
- **Domestic**

Included: All Scope 1 and 2 food based emissions

- **Food loss and waste**

Included: Methane generation from food in all waste streams.
Excluded: Human waste

Horizon Scanning: Main Novelty of WP1

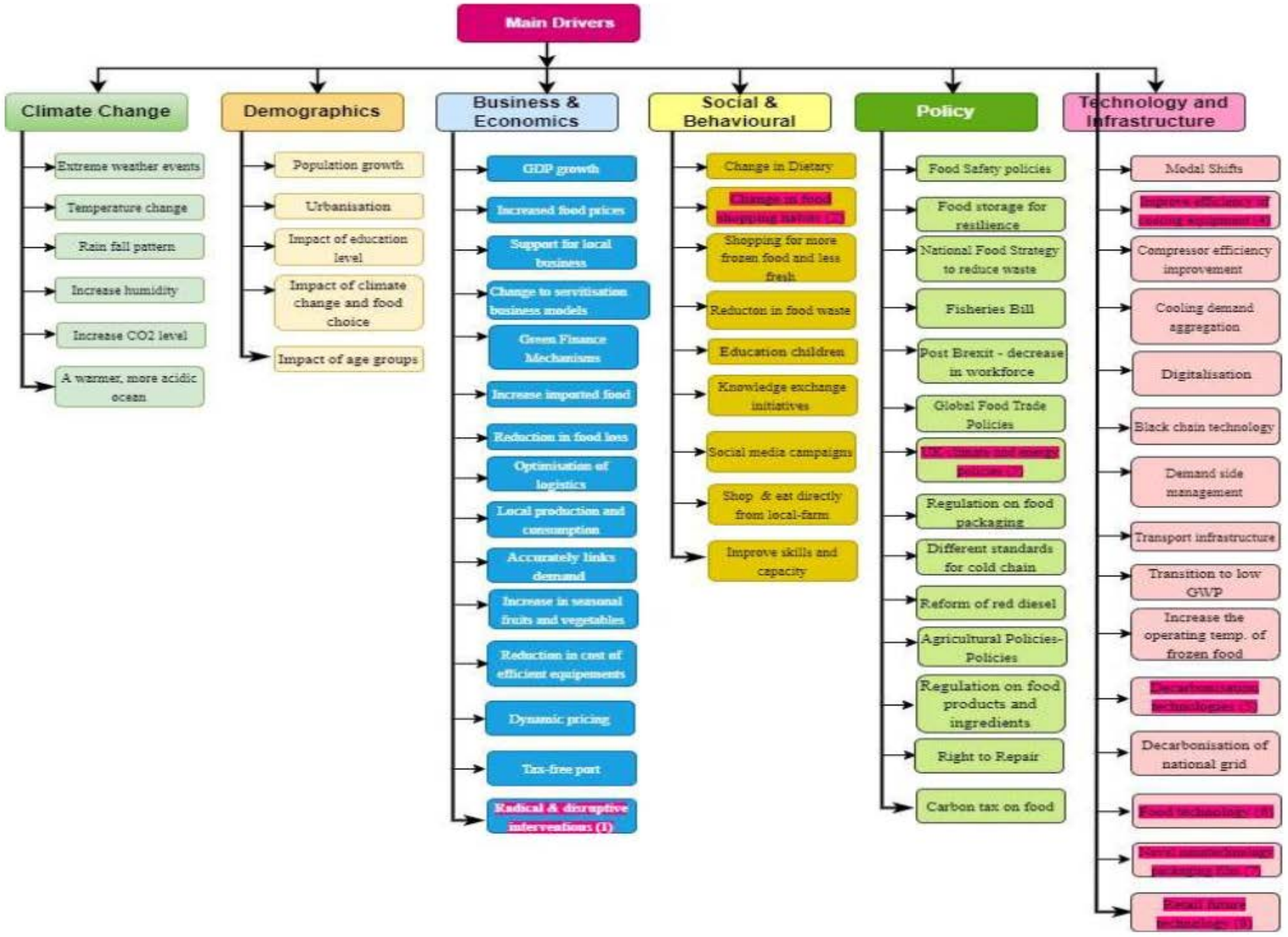
Why?

- **Accurate estimates** for 2030 and 2050.
- **Provide** with **scenarios** aligned with the future needs → achieve **Resilience**, **Mitigation**, **Adaptation** and **Inclusivity** in Europe.

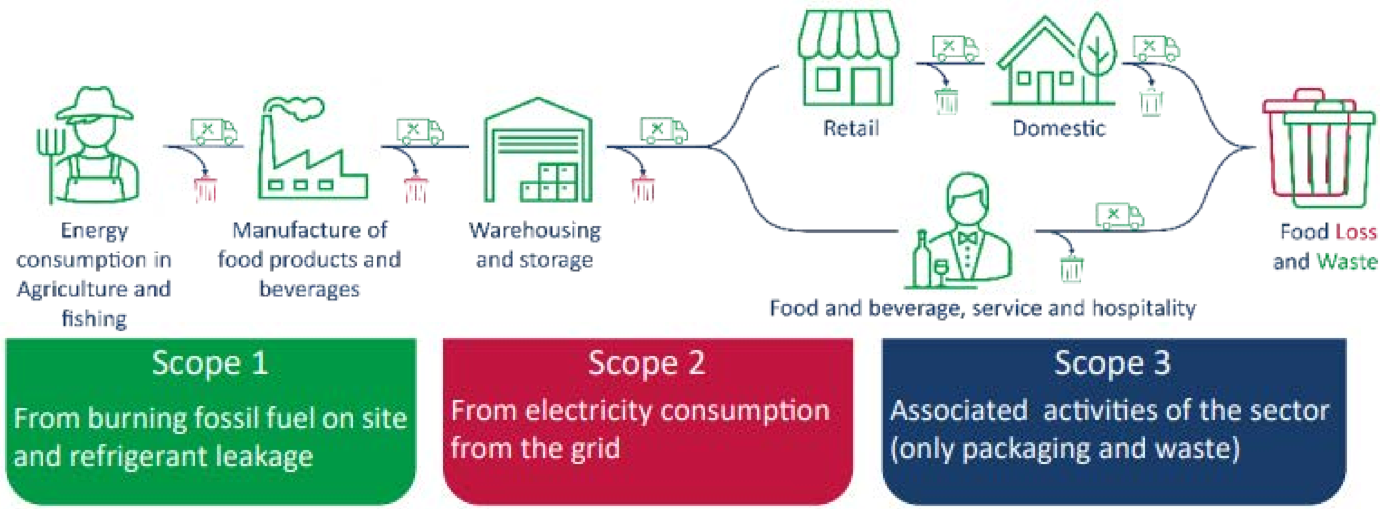
How?

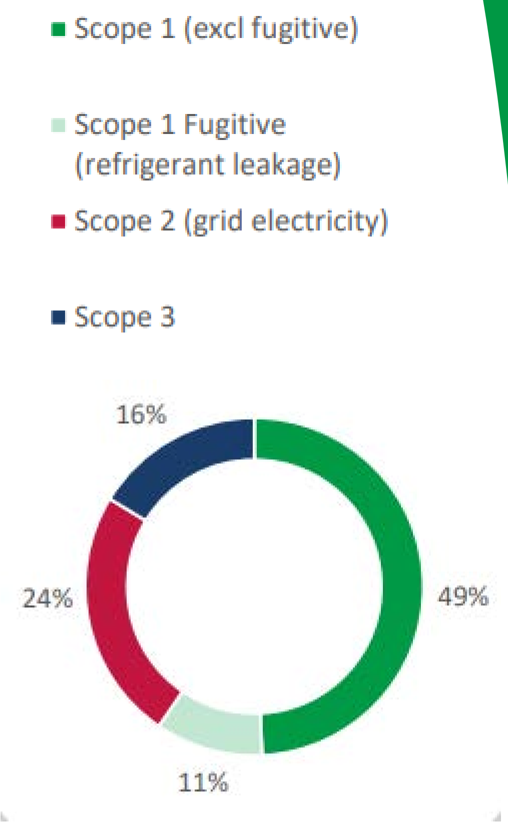
- Identifying the **main drivers (6)** and sub-drivers with greatest impact (on energy demand and emissions).
- **62 sub-drivers** and **32 sub-sub-drivers** (ex. change in food shopping habits: online shopping, more home cooking).
- For **each country**: Identify the top main **20 sub-drivers (Risks and Wins)** with greatest impact.

Step 1: Identify main drivers



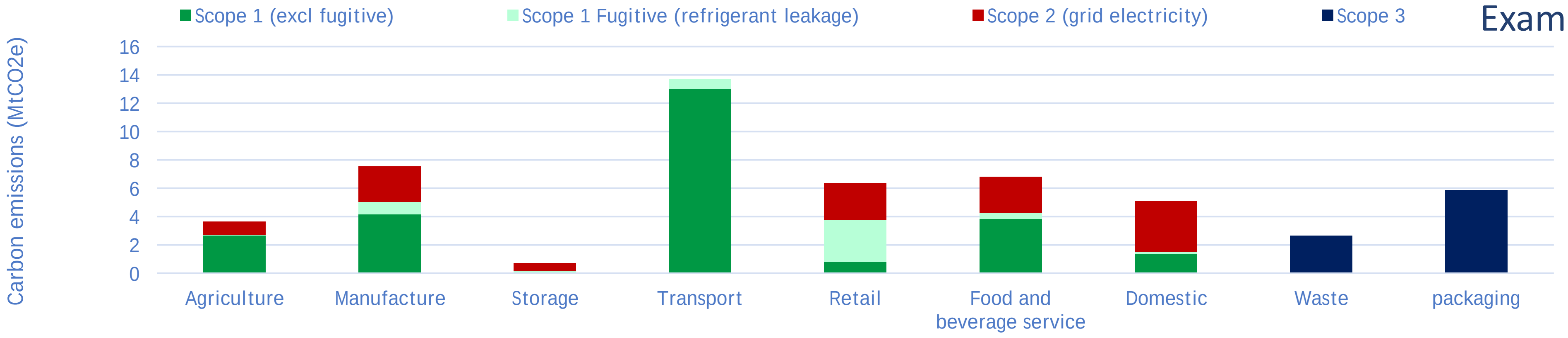
The Top-down Model





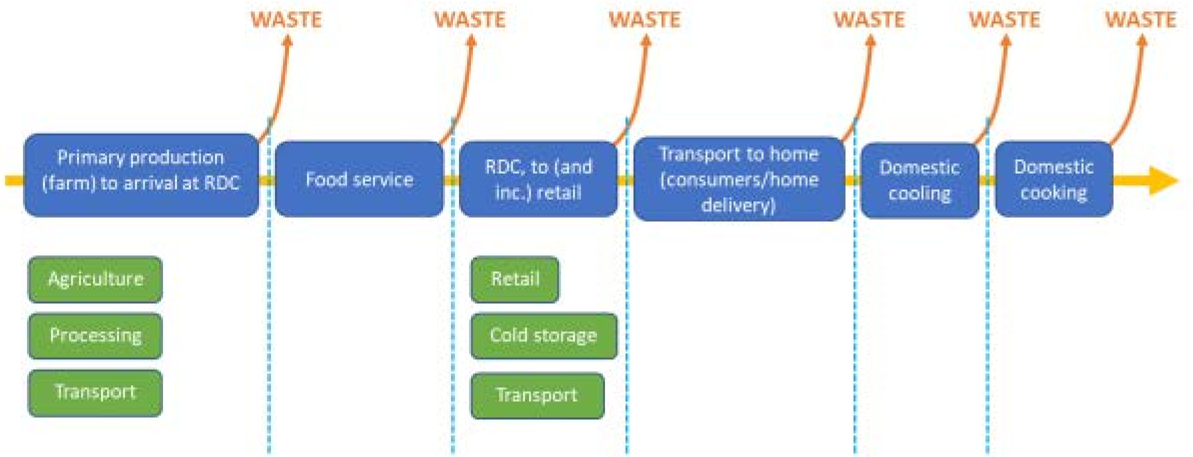
- Calculate scopes 1, 2 and 3 emissions for the identified sectors.
- Uses data from national statistics.
- Methodology tested and completed for the UK and Italy, in progress for other countries.
- A detailed guideline about the model is being prepared by the Italian partners CNR.

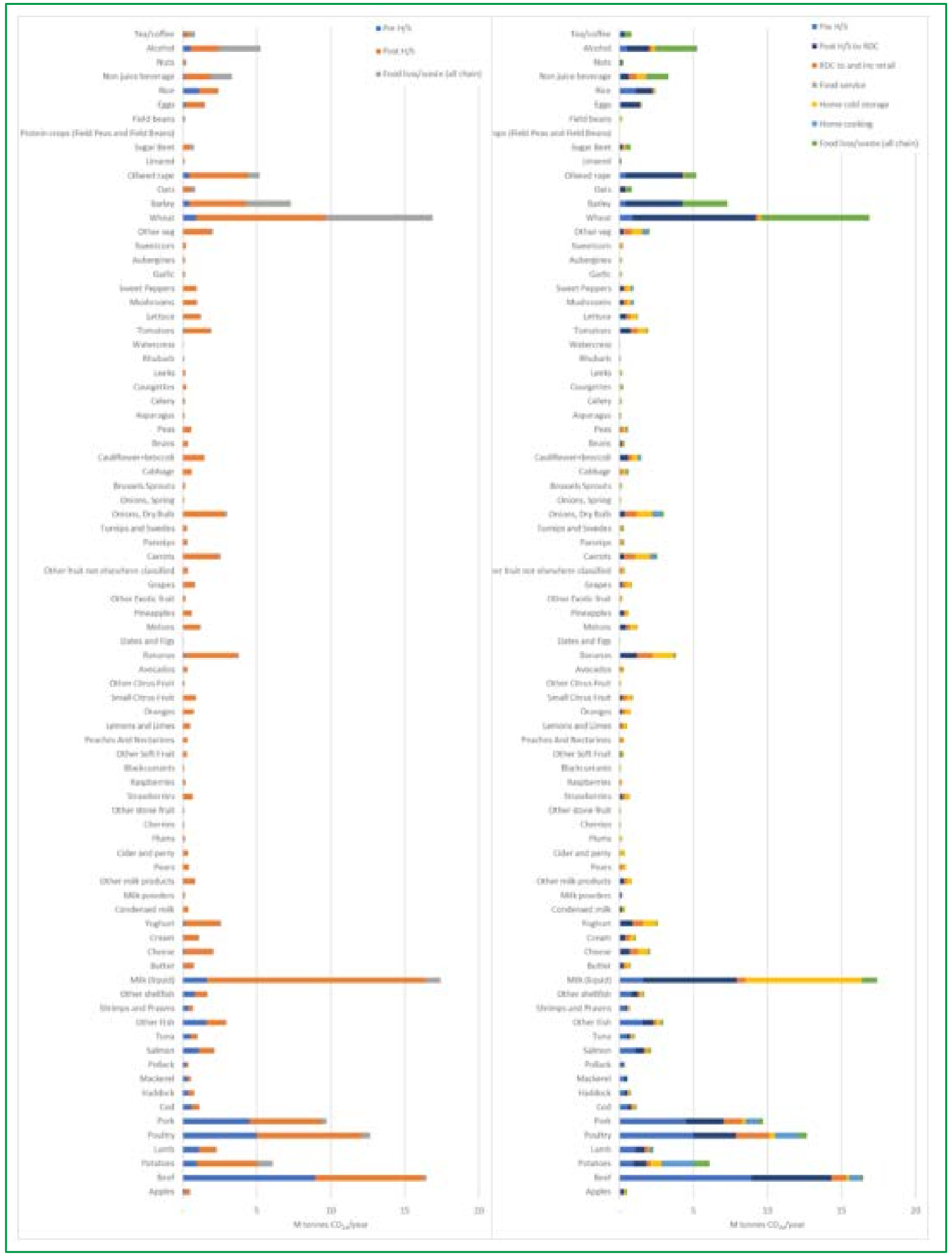
Example for the UK



The Bottom-up Model

Example for the UK

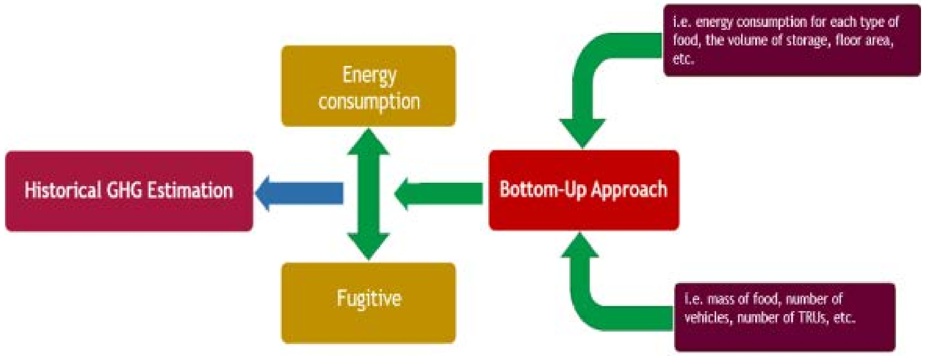


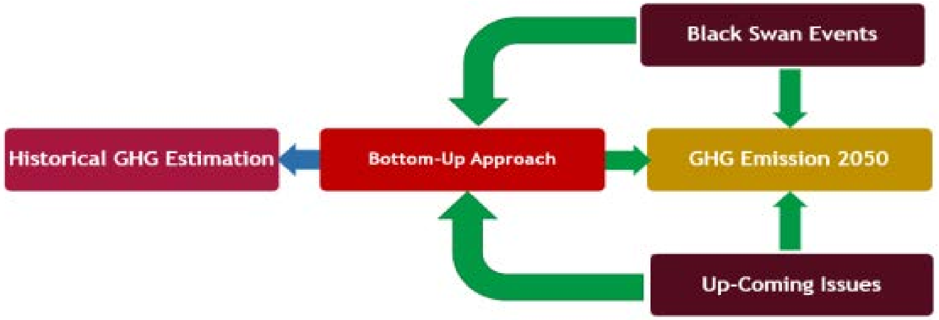


- A model under development for the UK, countries to provide with their own data.
- A production based model for all types of food to calculate Scopes 1, 2 and 3 emissions.
- **A large database** including **83 food types** is performed.
- **More granularity** compared to previous work (Audsley et al. (2009).
- For one country, emissions through the different stages based on mass of food produced, imported and exported.
- CO2e/kg figures from national statistics.

The Hybrid model

- A model being developed by UoB for the UK, countries to provide with their own data.
- Combination of top-down, bottom up, stock data, SEC for each food type.
- Calculates Scopes 1, 2, 3 emissions for baseline years based on energy consumption and refrigerant leakage.
- E.g. for cold stores: total number of cold storages and stock of refrigeration units. Number of vehicles, TRU and fuel consume etc.
- Implements drivers model to calculate future emissions in a yearly basis until 2050
- Compare scenarios and identify the one providing with lowest GHG emissions in 2050 (BAU and other future scenarios).
- Test against black Swan events to check their sustainability and resilience.





Results:

The highest EC sectors:

1. **Transport (all) = 51.67 TWh**
2. **Processing = 34.04 TWh**
3. **Domestic & FS = 28.6 & 28.3 TWh**

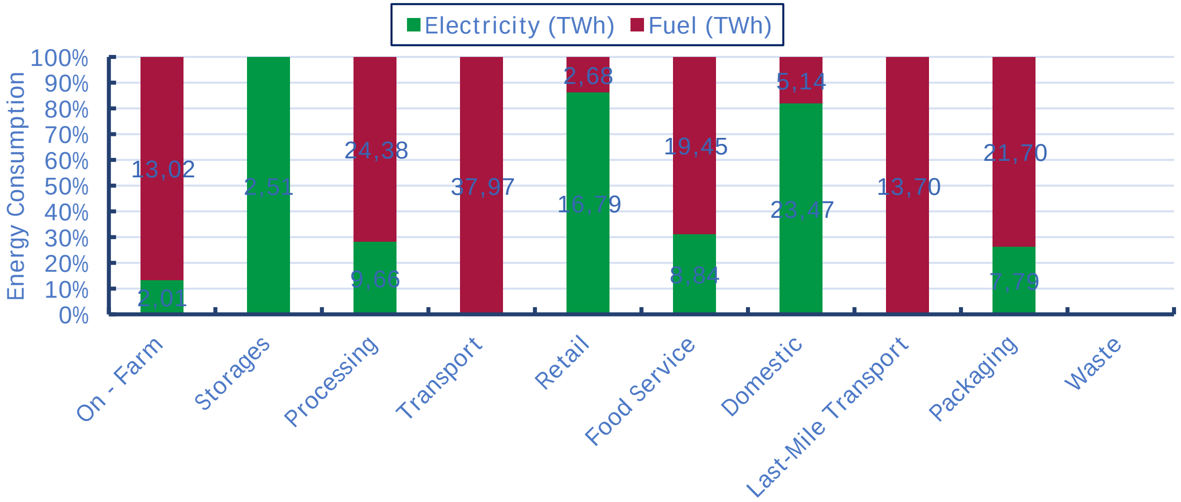


Fig. 1. Energy consumption by the UK food supply chain for the baseline year 2019.

- **Total energy consumption = 209 TWh**

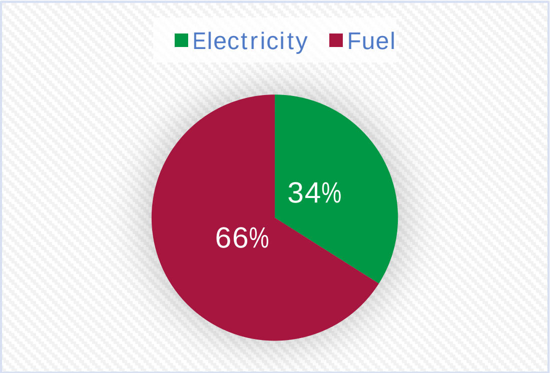


Fig. 2. Distribution of consumed energy.

Emissions:

- **Present Model: Total Emissions = 52.9 MtCO2e**
- **Top-down Model: Total Emissions = 51.67 MtCO2e**
- **Overall Divergence = 2.5%**

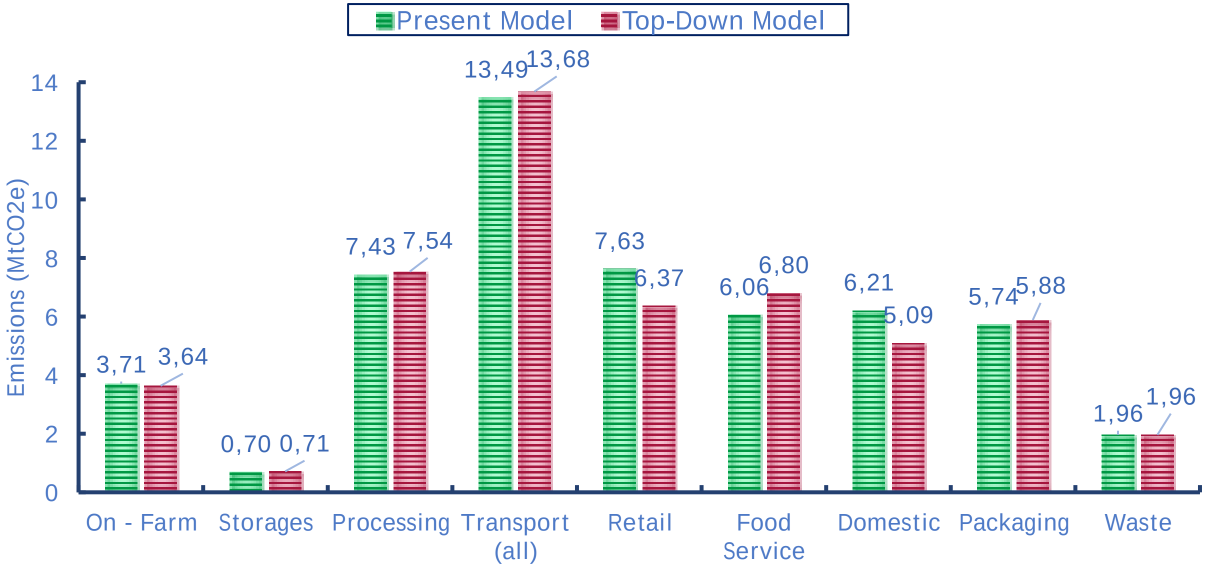


Fig. 3. Comparison between the present model and top-down model results for all sectors.

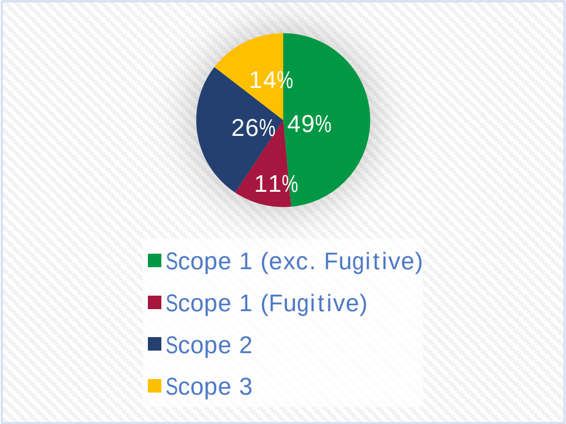


Fig. 4. Emissions by different scope(s).

Conclusions:

- **Good agreement is achieved with the high-level top-down model. Therefore, the hybrid model is ready to be used for detailed estimations until 2050.**

Factsheets

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

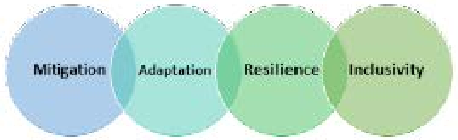
Factsheet 9
June 2023

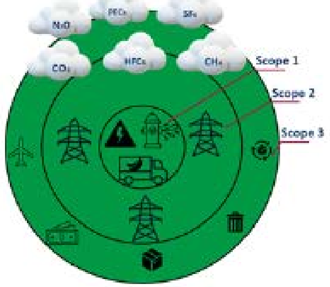
Towards the next generation of the European food supply chain: The ENOUGH Emissions Database

Part 1: Terminology

In Europe, 53% of the food system emissions are related to the supply chain. The ENOUGH project will establish an emissions database for 1990 and 2019 baselines and predict future (2030 and 2050) emissions for the European food supply chain, for a number of representative European countries. This will help to provide the EU Farm to Fork strategy with scenarios aligned with the future needs to achieve Mitigation, Adaptation, Resilience and Inclusivity of the European food sector.

ENOUGH will help to transition the EU food chain to become more sustainable, energy efficient and climate friendly.





Adopted terminology for the emissions

The project considers:

Scope 1 Emissions from on-site fuel combustion for heat and electricity generation, fuels used for food transport and refrigerant (f-gas) leakage from the refrigeration equipment.

Scope 2 Emissions from the energy generation (thermal or electrical) from the grid.

Scope 3 Emissions as a consequence of the activity of the sectors, in ENOUGH, only packaging and waste are included.

Horizon scanning is one of the main novelties being developed in the ENOUGH project. To establish a robust emissions database and predict accurate emissions figures for 2030 and 2050, the project has identified the potential main drivers of change that would positively or negatively impact carbon emissions from the food sector in the future.

The identified key drivers are: climate change, changes in demographics, business and economics, social and behavioral change, policy and technology and infrastructure. The key drivers are further refined into sub-drivers, these are indexed and scored for each representative country to identify the most impactful wins and risks subdrivers . At a later stage, the sub-drivers are implemented into emissions calculation models for an accurate and a country specific prediction of the future emissions.

Three models with different levels of complexities are being developed within the project to establish the baseline emissions and predict future emissions: These consist of a top-down, bottom-up and a hybrid model. The three model approaches will be compared to verify the consistency of results.

The top-down model uses national data on scope 1 and 2 emissions of each food chain sector together with scope 3 emissions from waste and packaging to calculate emissions.

The bottom-up model is based on mass of food passing though the food chain in a country and the associated emissions. To calculate the emissions from each sector and each food type, the model applies CO2eq/kg figures from published data.

The hybrid model combined elements of both the top-down and bottom-up models. The model uses data from government statistics, literature, trusted bodies e.g. Eurostat, UN, IEA etc.

Find more about this study from the original publication: 10.18462/iir.nh3-co2.2023.0033

ENOUGH webpage: https://enough-emissions.eu/
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Corresponding author: y.allouche@iifiir.org

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101036588

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EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

Factsheet 10
June 2023

Towards the next generation of the European food supply chain: The ENOUGH Emissions Database

Part 2: Boundaries

Several trusted inventories have established emissions database for a large number of countries e.g. FAO STATS, EDGAR. However, inventories often apply different boundaries which makes the figures difficult to compare. In ENOUGH, clear boundaries are identified within the food supply chain. Uncertainty calculations are performed, and emissions figures compared with those obtained in the existing inventories.

ENOUGH food supply chain sectors

In ENOUGH, we are developing a robust methodology to calculate the emissions from the food supply chain sectors including: agriculture and fishing, manufacture of food products and beverages, packaging, warehousing and storage, transport, retail, food service and hospitality, domestic food related activities and food loss and waste.

Emissions are calculated for both perishable (needing refrigeration) and non-perishable food and beverages (which can be stored at ambient temperature) for human consumption.

Geographical Boundaries

European Union, European Economic Area and the UK: for all the project demonstrators and emissions quantification work. To calculate the emissions from the food supply chain, a number of representative European countries are selected including the UK, Norway, France, Italy, Germany, Austria, Lithuania, Poland, Hungary and Belgium. We do not include emissions related to chain before arriving or once leaving the European boarders.

Supply chain Boundaries

In agriculture and fishing, only emissions from energy consumption of the farm equipment are calculated. Those from fertilizers, chemicals and land use change are excluded.

In manufacture of food products and beverages, only emissions from energy use in processes are calculated, those from manufacturing and end of Life (EOL) of primary materials are excluded.

In packaging, both emissions from raw materials and packaging manufacturing are included, those from packaging EOL and recycling are excluded.

ENOUGH representative countries

In warehousing and storage, emissions from energy consumption related to food and refrigerant leakage are calculated.

In transport, fuel consumption by refrigerated and non- refrigerated land, air and maritime vehicles are calculated, alongside refrigerant leakage from Transport Refrigerated Units (TRUs). This also includes last mile delivery and domestic car food transport.

In Retail, emissions from energy consumption related to food (including food services integrated onto the retailer) and refrigerant leakage are calculated.

For both domestic, and food and beverage service and hospitality sectors, energy consumption from cooking and refrigeration, as well as emissions from refrigerant leakage are calculated.

In food loss and waste, methane emissions from solid waste disposal on land, biological treatment of solid waste, wastewater handling related to food and waste incineration are included. Human waste is excluded.

Emissions from refrigerants are those associated to the refrigerant leakage from the moment it is filled in the equipment until its disposal.

Find more about this study from the original publication: 10.18462/iir.nh3-co2.2023.0033

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THANK YOU !

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EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

HOW TO REDUCE ENERGY CONSUMPTION AND CARBON EMISSIONS IN SUPERMARKETS?

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EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

WORKSHOP 16
Data and Models to Quantify CO_2 Emissions in Cold Chain and Food Systems

ELIAS EID
London South Bank University (LSBU)

26th International Congress of Refrigeration
Thursday August 24th, 2023
Paris Congress Center – Room 352A

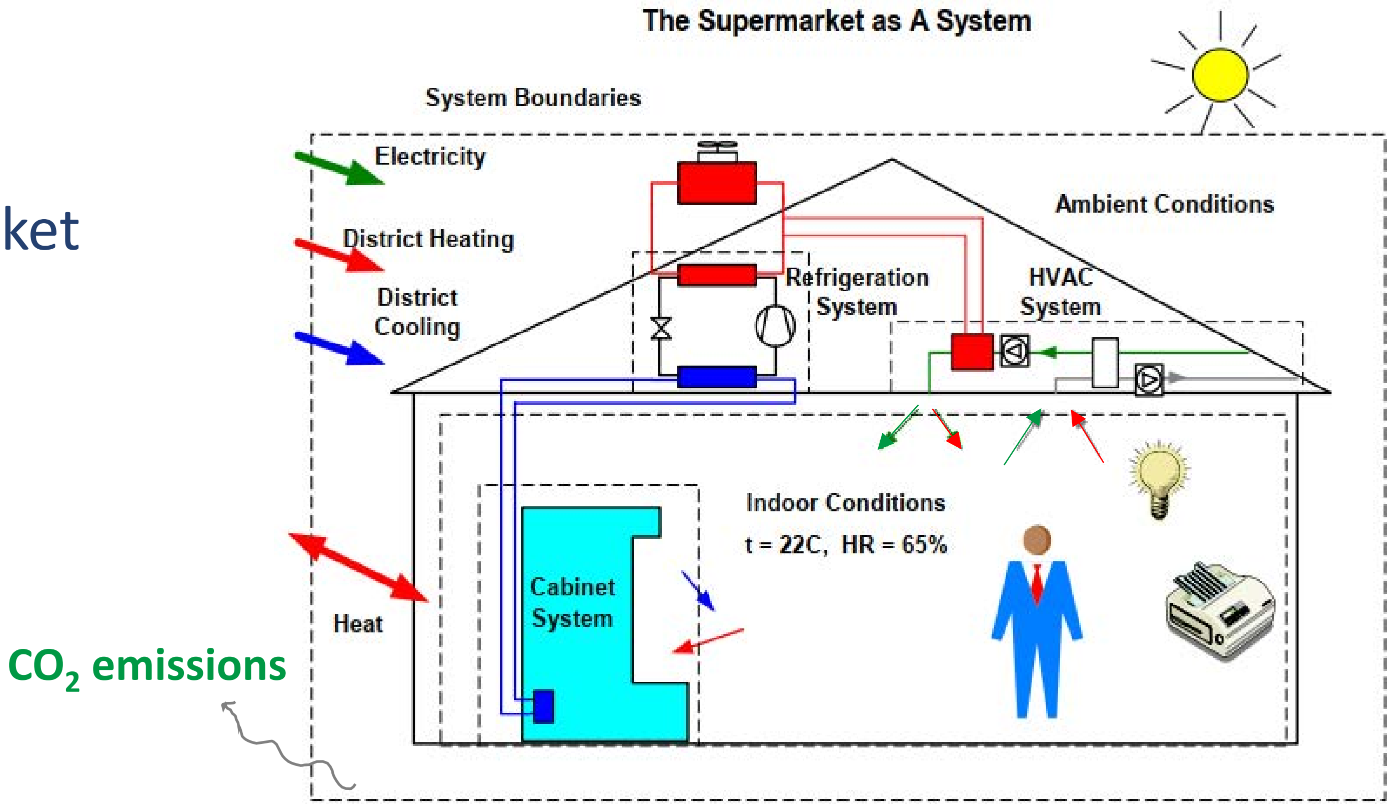
Introduction

- **Problem statement**

Various boundaries of a supermarket

- HVAC system
- Refrigeration system
- Cabinet system
- Heating sources
- Lighting and equipment

The supermarket is a complex system that needs to be studied with all interactions



A conceptual scheme of the different subsystems in a supermarket and their interconnections

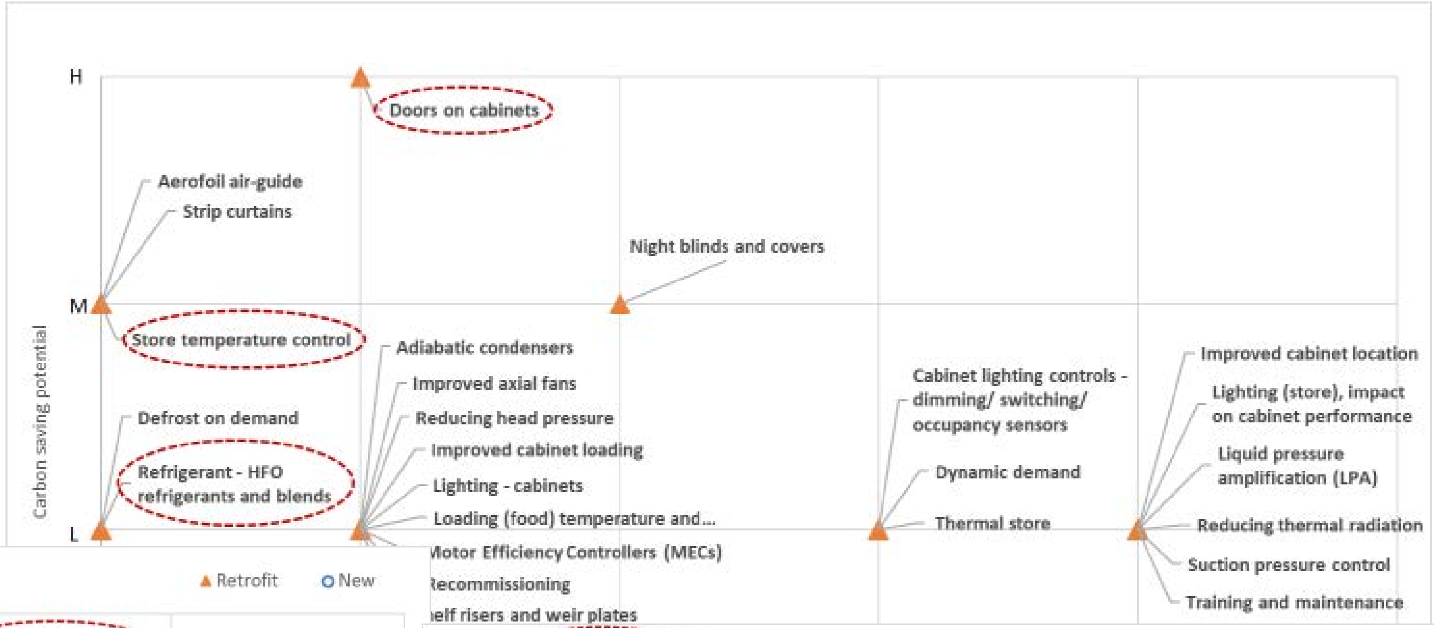
(Arias J., (2005). *Energy Usage in supermarkets)*

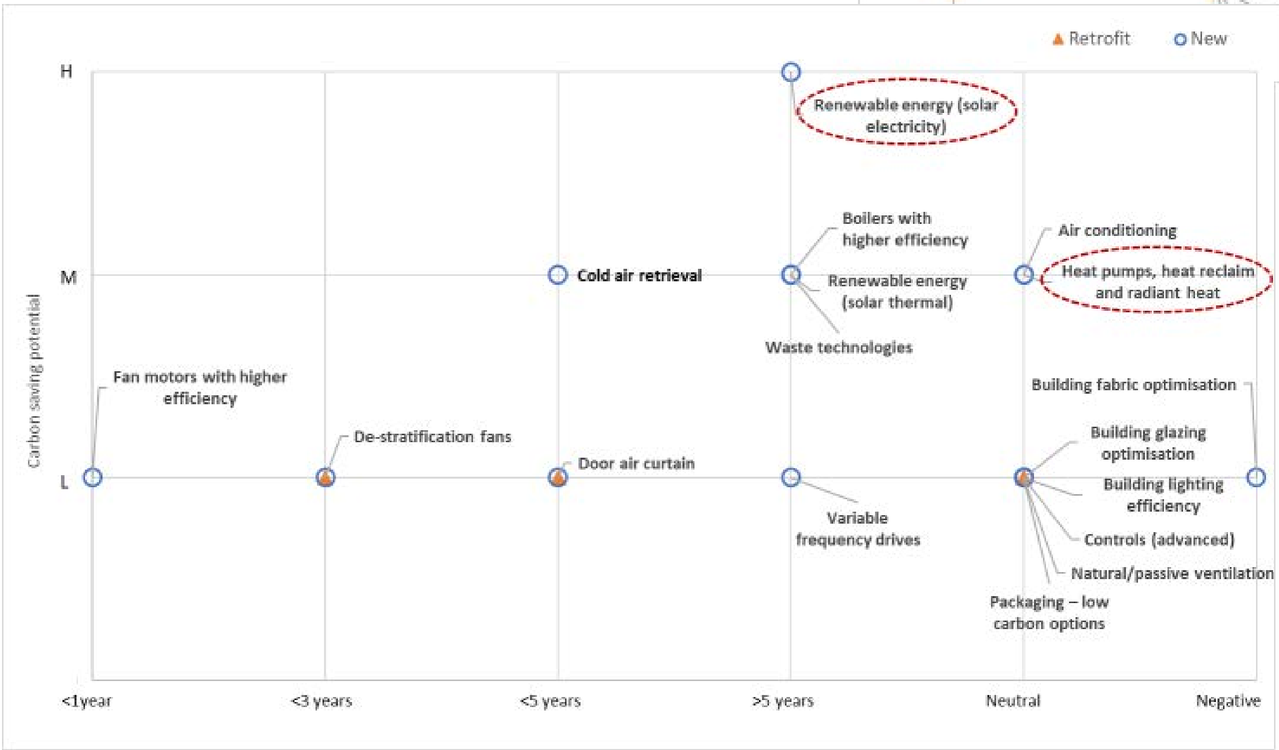
Retail road map

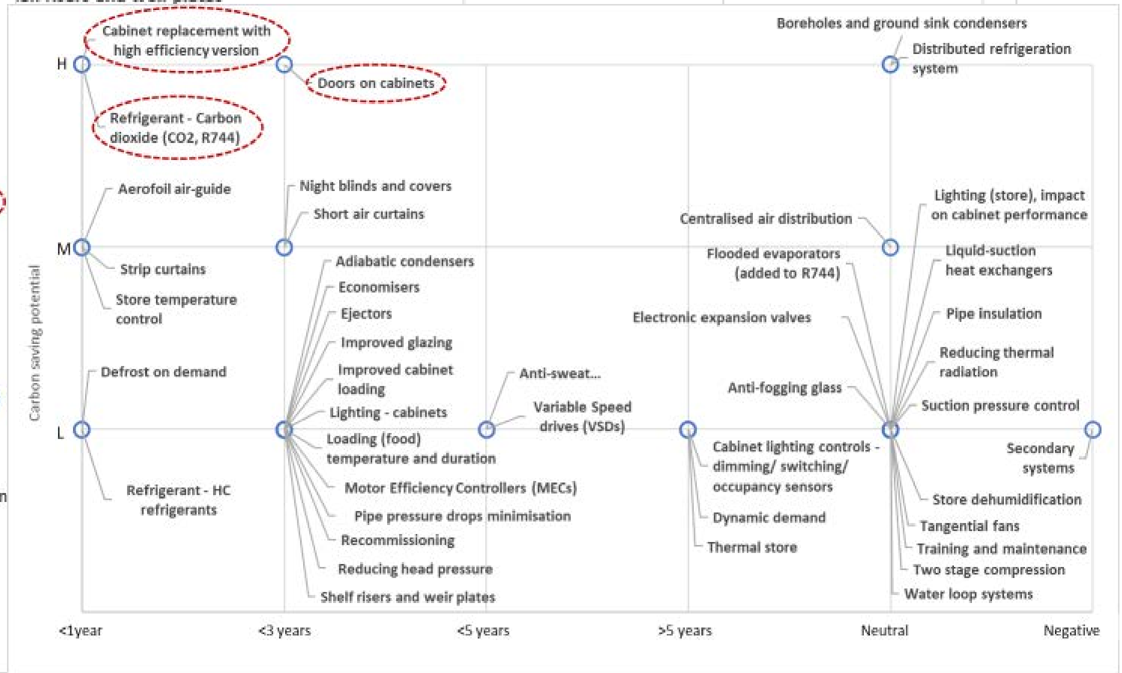
- **Part of ENOUGH project** (also road maps for other food sectors)
- **Aims to:**
  1. Identify the most beneficial technologies to save energy and carbon emissions for the whole supermarket as a system
  2. See how close to net zero is achievable
- **Three stages:**
  1. Identify and review technologies
  2. Model supermarkets
  3. Create road map for retail sector

Technology review

- Initial assessment based on reviewing technologies
- Best options were chosen for modelling







Modelling scenarios

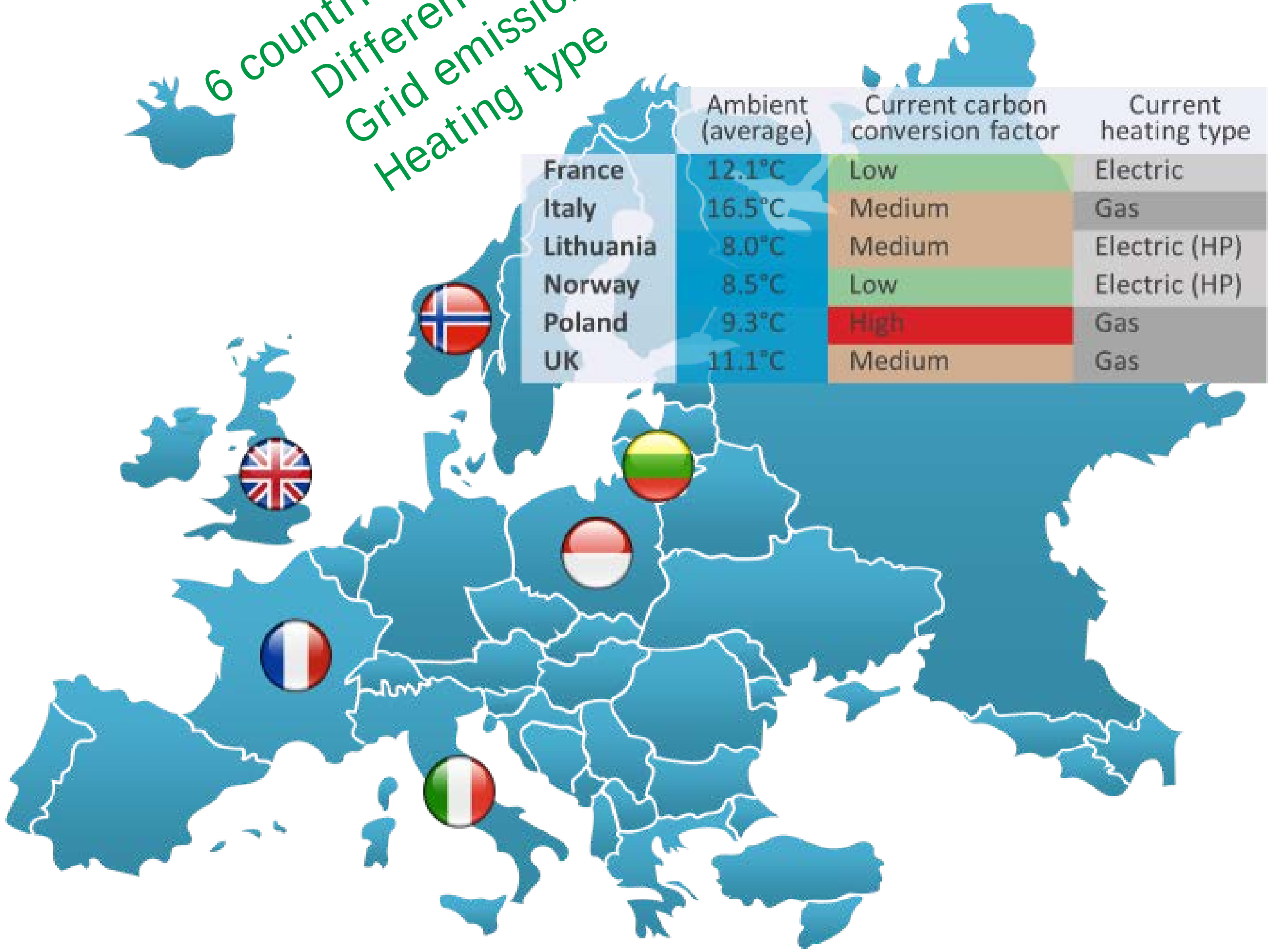
- 2 supermarket sizes (2,100 and 600 m^2)
- 3 scenarios between 2020 and 2050

Do nothing
- Assume changes to electrical generation carbon conversion factor
- Global warming continues as predicted

Minor retrofit
- Doors on cabinets
- HFO refrigerants (small stores)
- Increase dead band of store ambient temperature by 2K

Major retrofit
- Apply R744 (to small stores)
- Better cabinets (20%)
- Heat pumps for heating
- RES (solar)

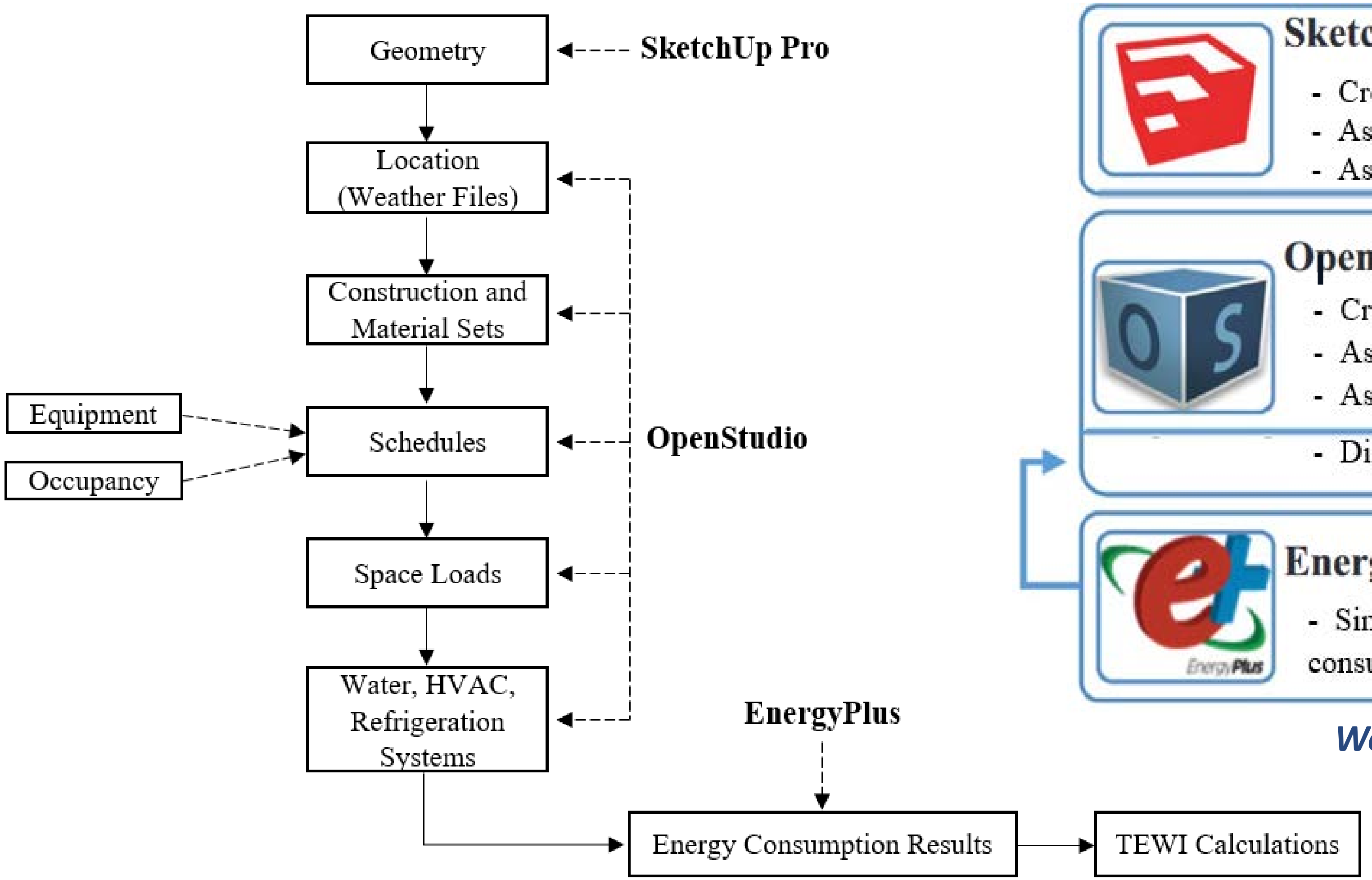
6 countries:
Different locations
Grid emission factors
Heating type

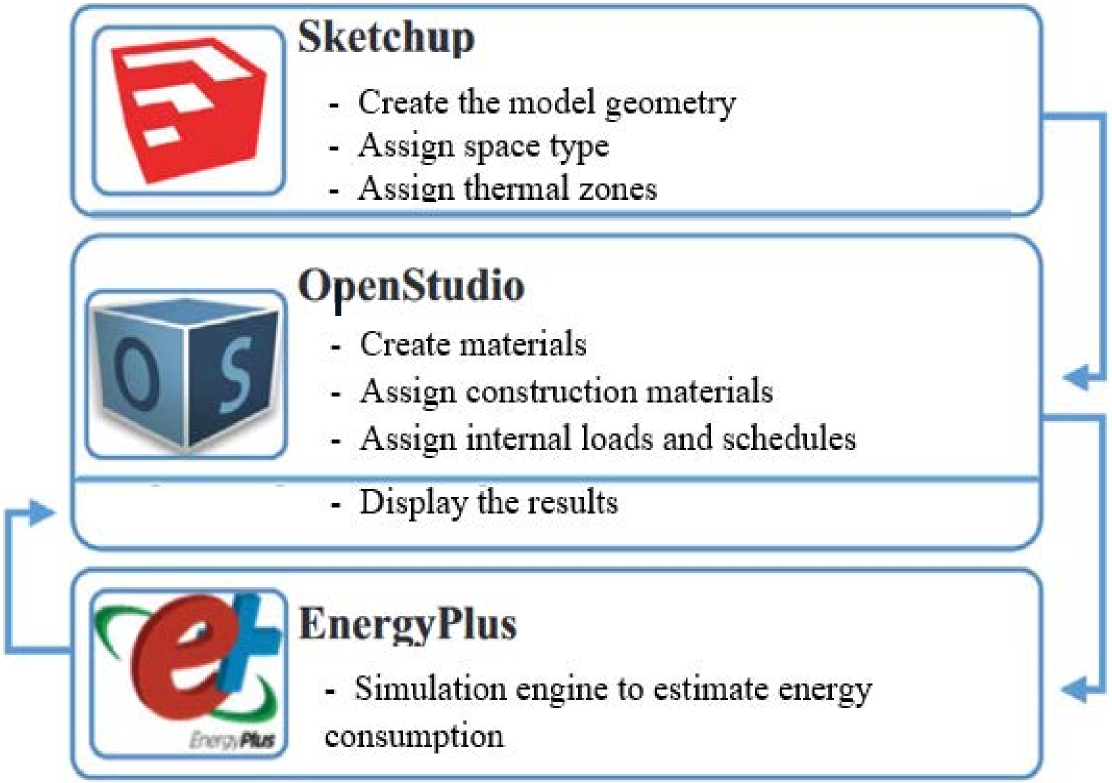


	Ambient (average)	Current carbon conversion factor	Current heating type
France	12.1°C	Low	Electric
Italy	16.5°C	Medium	Gas
Lithuania	8.0°C	Medium	Electric (HP)
Norway	8.5°C	Low	Electric (HP)
Poland	9.3°C	High	Gas
UK	11.1°C	Medium	Gas

Modelling methodology

- Three programs were used

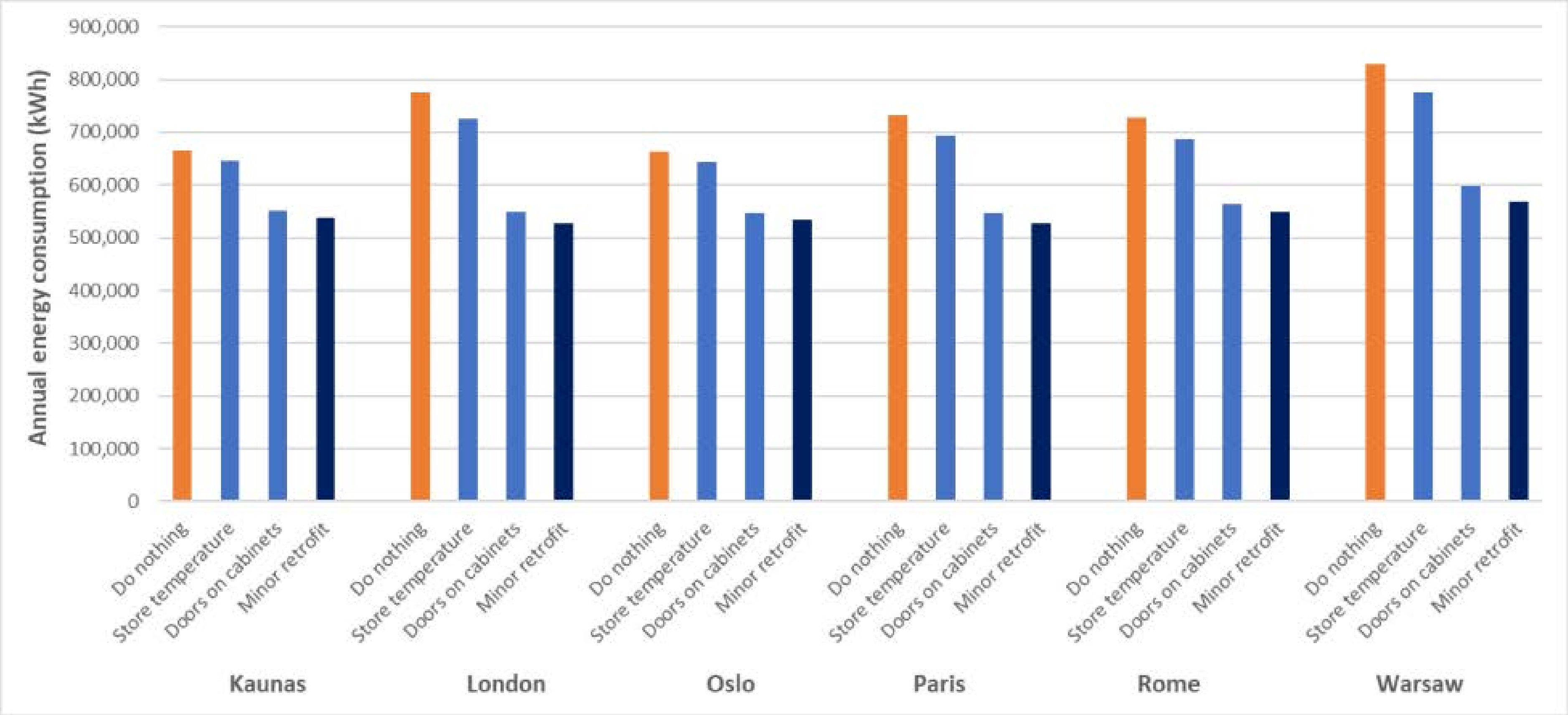




Workflow for modelling

Results – Energy consumption

- Example (medium supermarket) – Minor retrofit



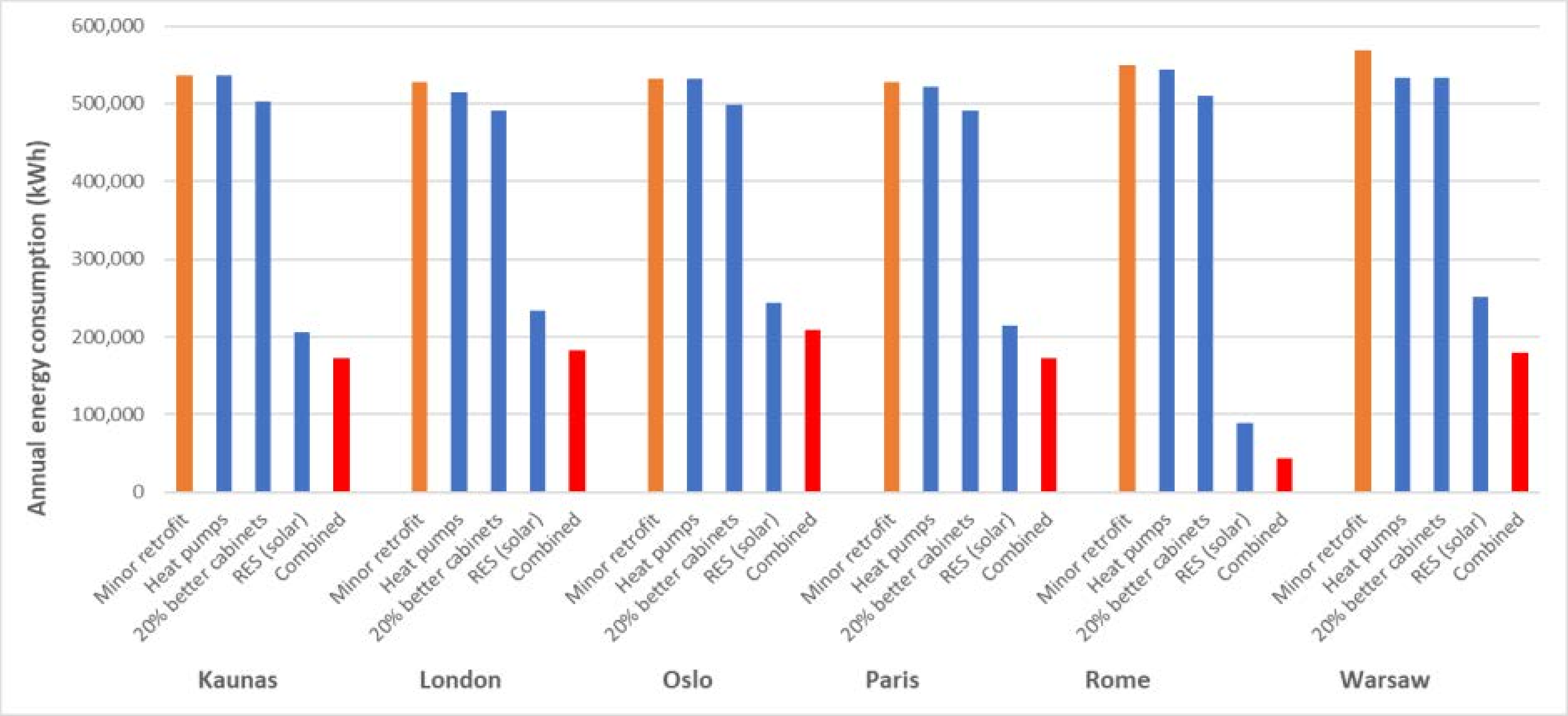
Starting with the Do nothing scenario

Applying technologies individually to study their effect

Combining them to get the Minor retrofit model

Results – Energy consumption

- Example (medium supermarket) – Major retrofit



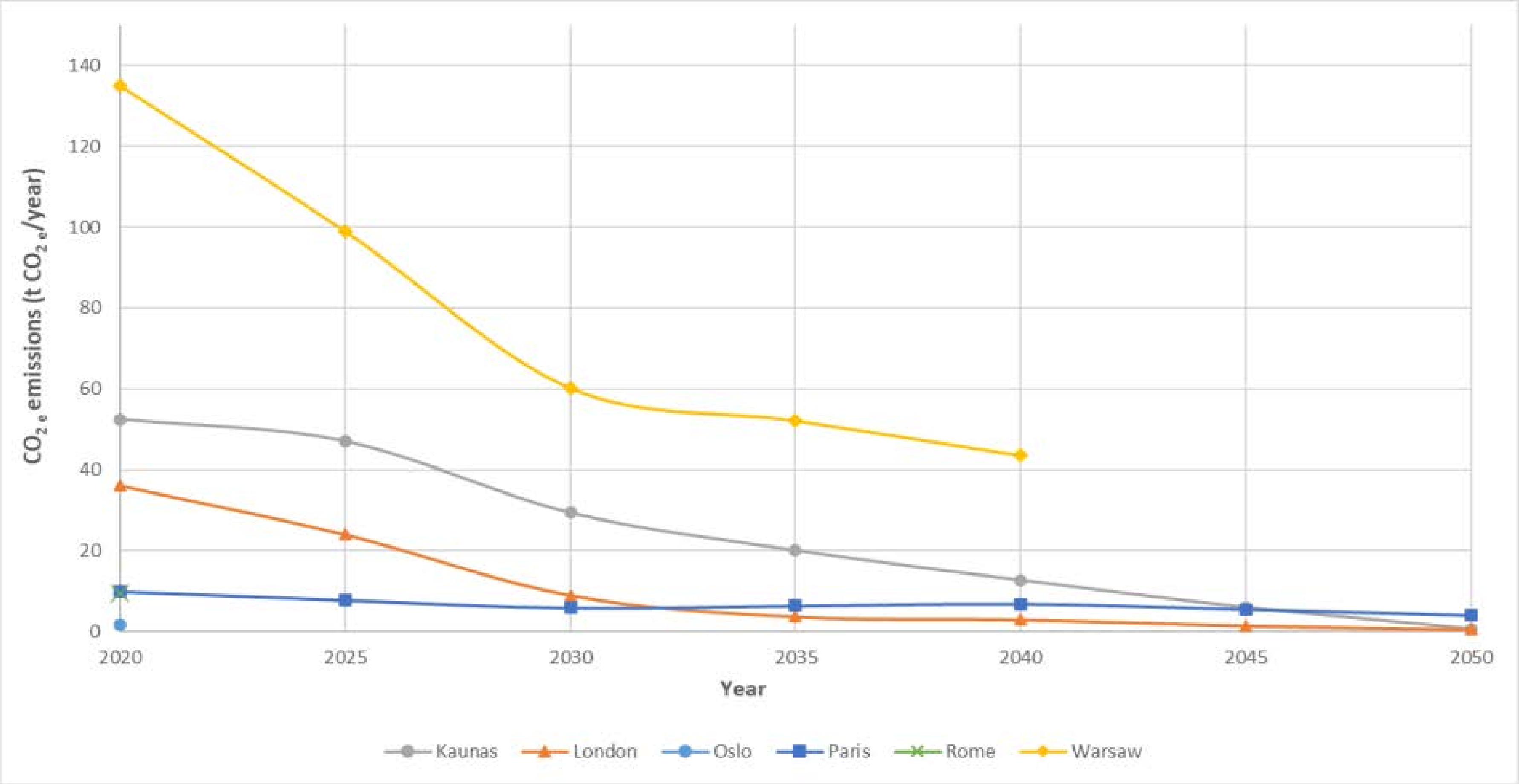
Same methodology

Applying technologies individually

Combining them to get the Major retrofit model (combined)

Results – Carbon emissions

- Example (medium supermarket) – Major retrofit



Lithuania and UK: predicted to reach almost zero by 2050

France: already has a low grid conversion factor and is near zero by 2050

Italy and Norway: no official information on grid carbon intensity but a potential to decarbonize in Italy and Norway is already near zero

Poland: although the grid is decarbonizing, still high level in 2040

Main conclusions and recommendations

- Carbon emission savings between **59%** and **97%** were achieved

Depending on location, grid carbon conversion factors and technologies

Diagram showing the priority areas for supermarkets to focus on

Important to act quickly to maximise both energy and carbon savings

All examined technologies are available today

The opportunity to reach near zero carbon for supermarkets exists and is feasible !

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101036588

ENOUGH

EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

THANK YOU FOR YOUR ATTENTION

enough-emissions.eu

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EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

The ENOUGH tool

Simulating energy and CO2 emissions of food supply chains

Denis Leducq
INRAE

IIR Workshop

24/08/2023

Objectives

An assessment tool **at the scale of a food supply chain**

- To provide insight on global numbers (countries, food sectors…)
- To identify the greatest potentials of reduction

60% of food should be refrigerated at some point

Approximately 70% of emissions from food are related to **perishable foods**

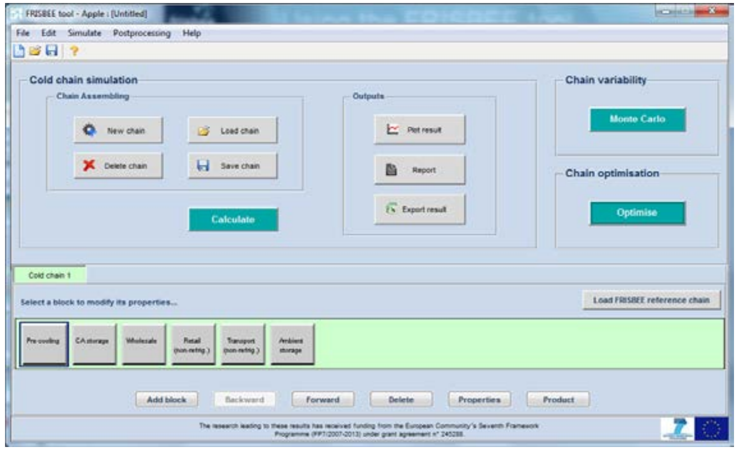
- To include food quality as a criteria

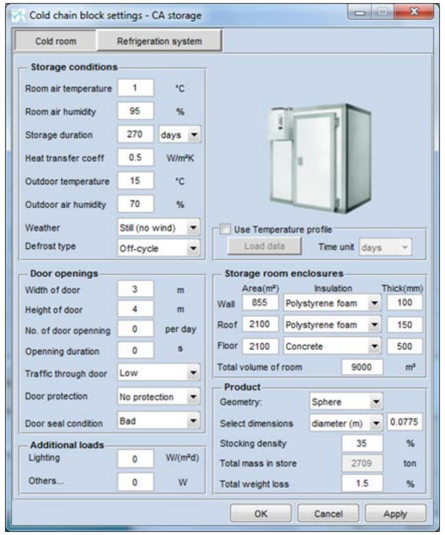
A tool to help food industry to **design and decarbonize** the food supply chains

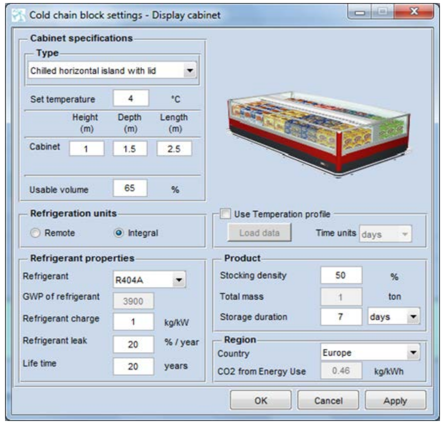
Background
FRISBEE TOOL

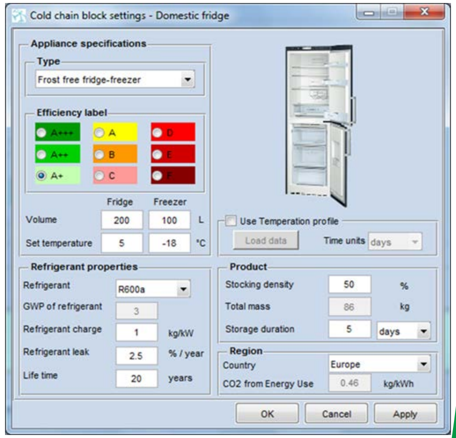
A Matlab application for Microsoft Windows

Allows the user to assess food cold chains with 3 criteria: food quality evolution, energy use and environmental impact (CO_2 emission)









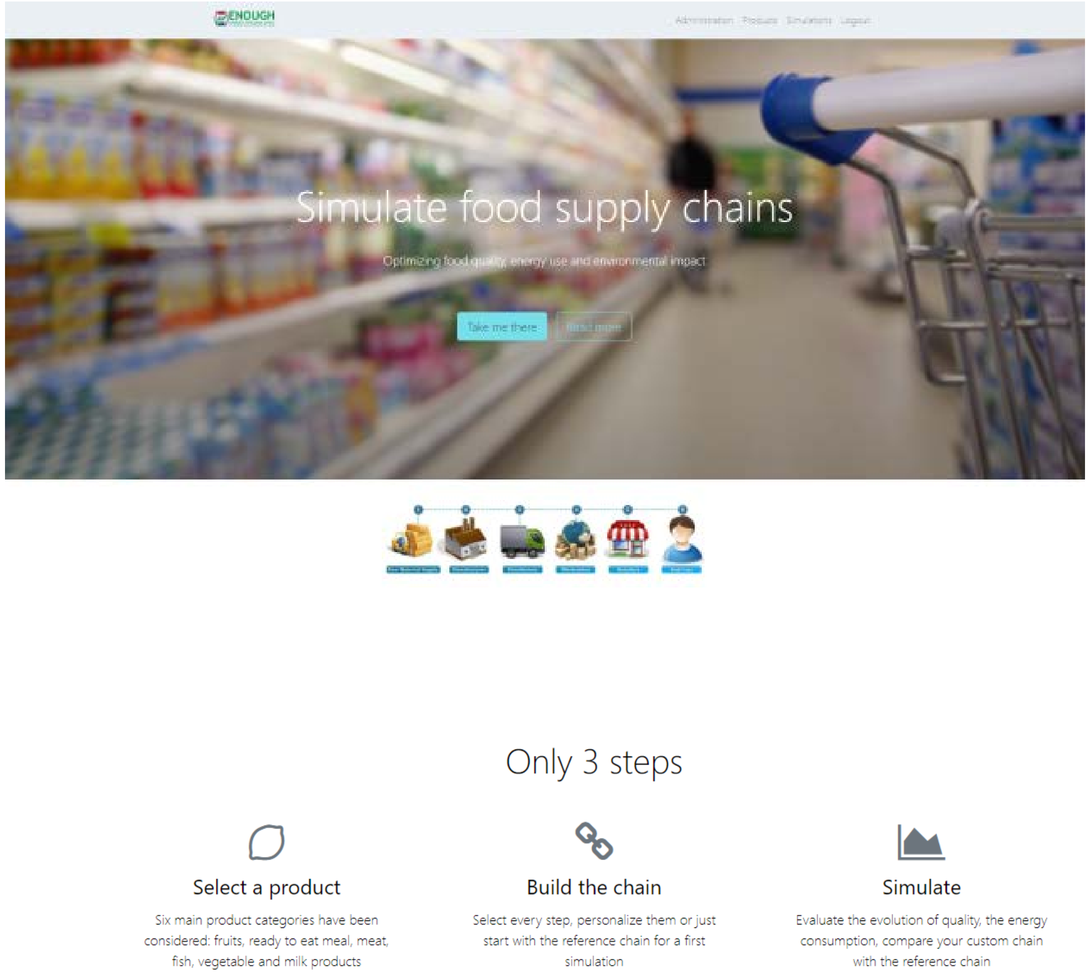
From Frisbee tool to ENOUGH tool

Extending the scope to every food supply chain

- Food processes (heating...)
- Transport
- Packaging
- Renewable energy sources
- Enlarged database of products

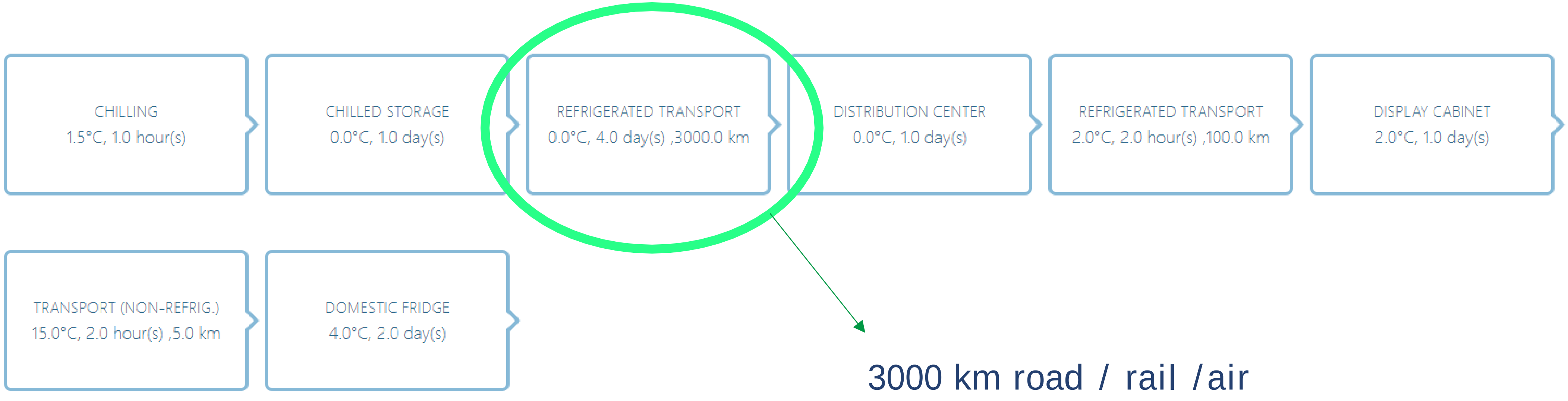
To simplify the installation and use of the software

- Matlab => web application



Example of simulation
Salmon chain

- Road / rail / air, transport mode comparison



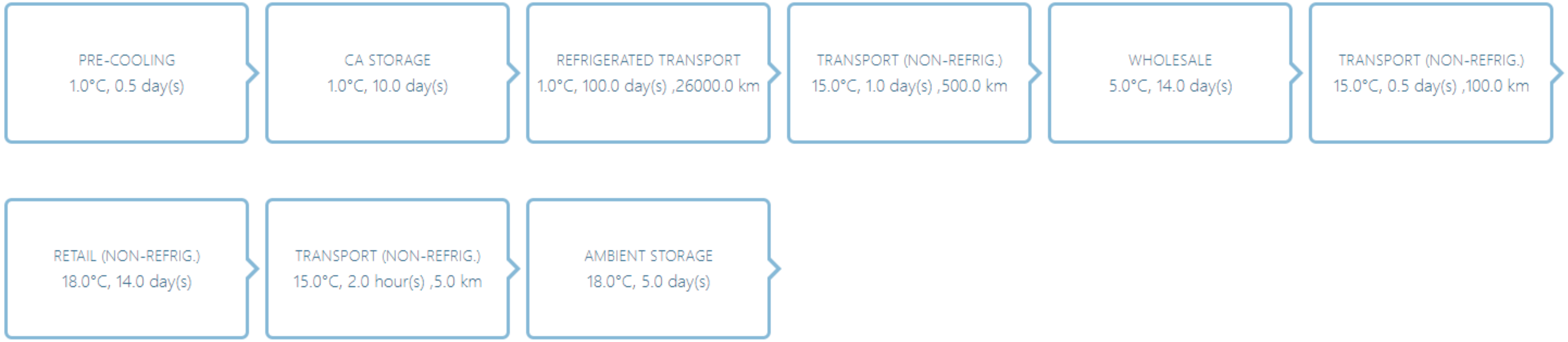
Example of simulation

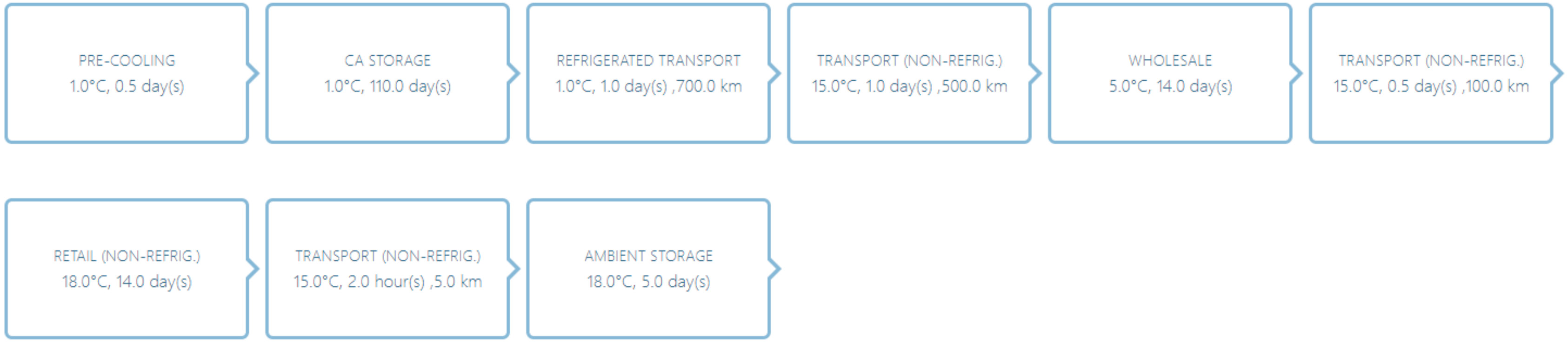
Road / rail (electric) / air – results comparison

For this example, emissions more than 10 times higher if air transport

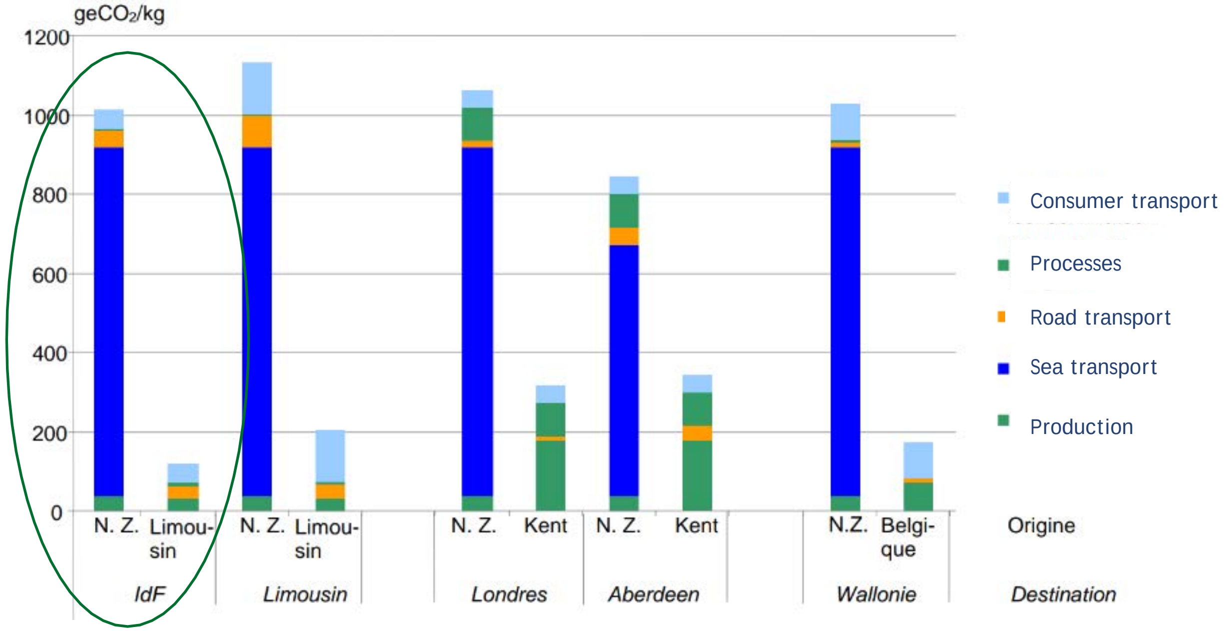
Example of simulation
Apple chains from New Zealand / France, retail in Paris

- Example from Rizet, M. Browne, J. Léonardi, J. Allen, M. Piotrowska, et al.. Chaînes logistiques et consommation d'énergie : cas des meubles et des fruits et légumes. 2008, 167p. hal-00544563





Results



Emissions more than 10 times higher for an apple produced in NZ

Perspective

- Frisbee tool still available
  - web site https://www.frisbeetool.eu/

- Enough tool still in development, but already available
  - Can be accessed through the ENOUGH web site https://enough-emissions.eu/

- Next version will not only simulate food supply chains, but will suggest solutions to decarbonize simulated chains

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101036588

ENOUGH

EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

Thank you for your attention

enough-emissions.eu

Quantifying Cold Chain Carbon Emissions

Dennis Nasuta, OTS R&D

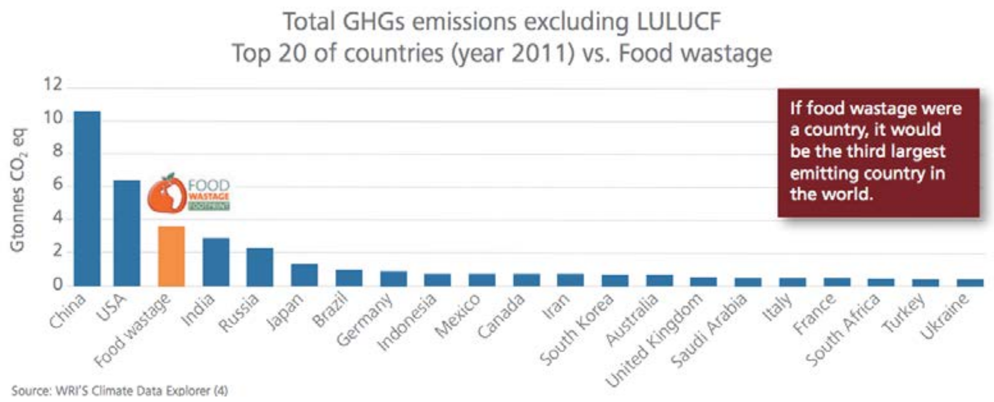
Rajan Rajendran, Copeland

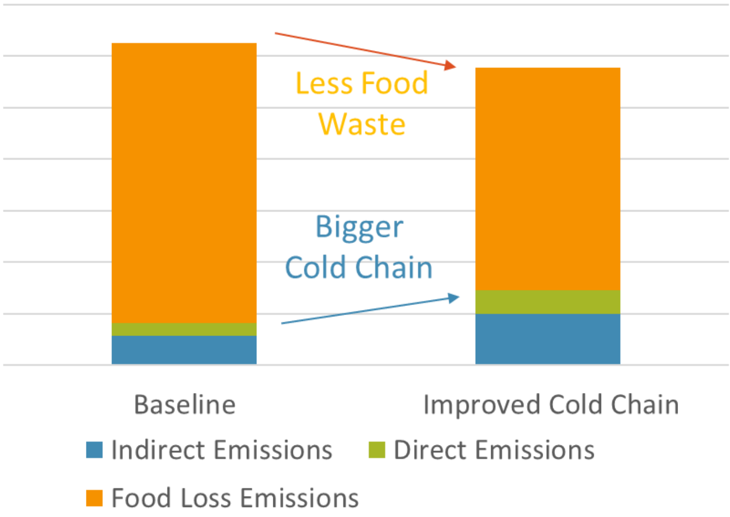
August 2023

GLOBAL FOOD COLD CHAIN COUNCIL

Big Picture

- Food system accounts for 18Gt CO_2-eq., one third of total GHG emissions (Crippa 2021). About one third of food is lost or wasted (FAO, 2014)
- A significant portion of losses could be avoided with an expanded cold chain. Research has shown the avoided emissions exceed the equipment emissions (IIR, GFCCC)
- Refrigeration equipment will need to more than double by 2050 (Peters, 2018)





- There is an unmet need to quantify food losses, current cold chain, and the impact of cold chain improvements

Past Work

- **2010** James and James- one of the first to claim that cold chain expansion might be possible without net CO2 emissions increase, though no quantitative study
- **2014** FAO Food Wastage Footprint- methodology to quantify global food loss/waste and its impacts. Emissions from food loss were 3.3 Gt CO2-eq. annually
- **2015** GFCCC- team involved with FWF computed that if global cold chain was expanded to the level of developed countries, the emissions savings from food loss would be 10x the emissions increase from equipment
- **2019** Heard & Miller- studied Sub-Saharan Africa. Showed that other factors (agricultural and dietary shifts) could be highly significant. If a North America-like cold chain were adopted, emissions could decrease as much as 46% or increase by 10%
- **2021** IIR- global model for estimating net cold chain impact. Infers extent of cold chain equipment from food production and country characteristics (bottom-up approach). Estimated expanded cold chain benefit to be 1.8x more than equipment emissions
- Crippa; Tubiello- using top-down accounting of cold chain including reported refrigerant inventories, not estimating its impact on food loss avoidance
- GFCCC/UNEP OzonAction launch Cold Chain Database and Modeling Initiative

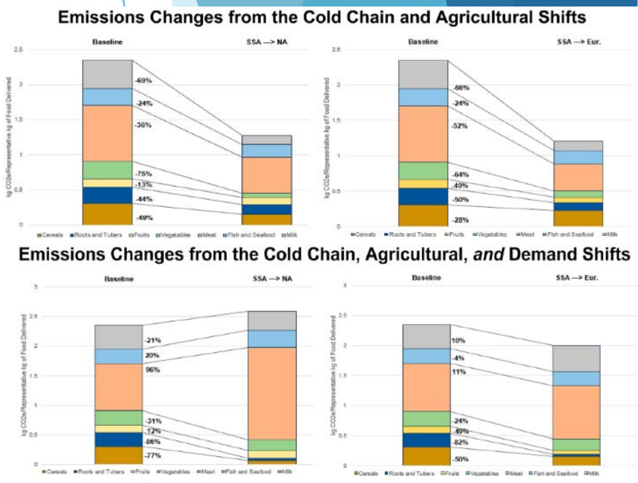
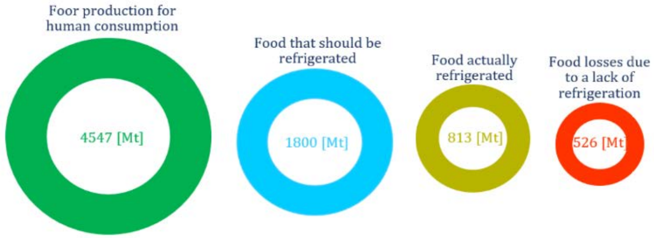
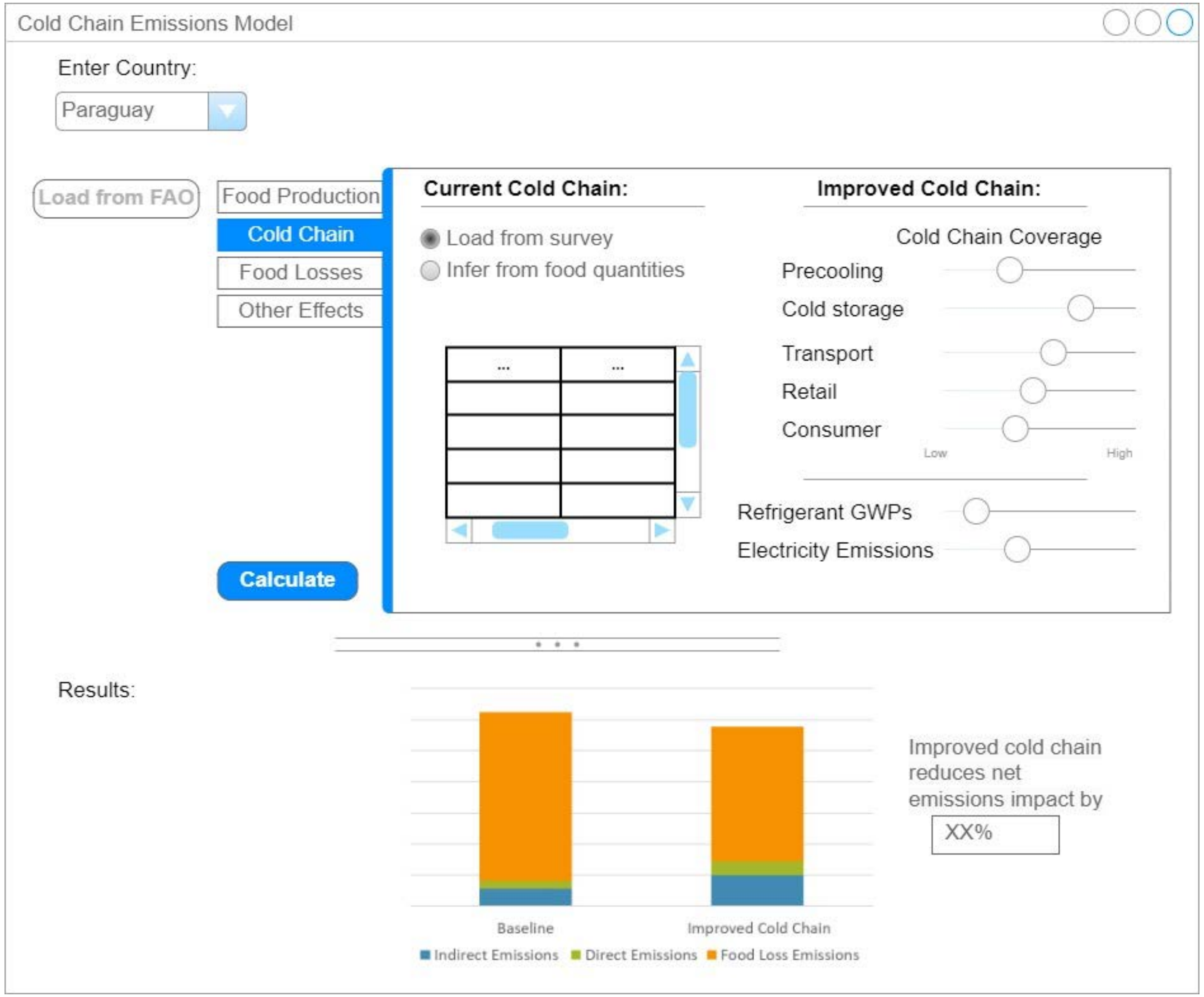


Figure 4. Changes in upstream food supply emissions (kg CO_2e) required to deliver one kg of a representative diet, based on a weighted average of each food type within a typical diet. Percentage differences in emissions are displayed by corresponding food type in the graph.

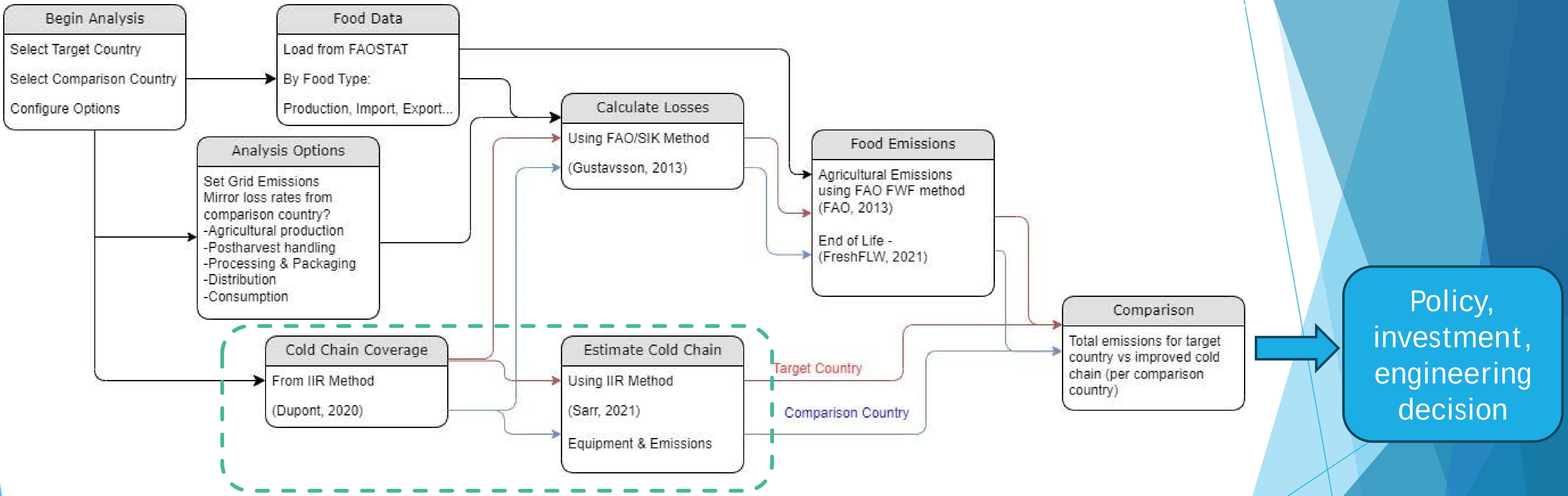


Modeling Goals



- Seeking a rapid, high-level method to evaluate emissions impacts of decisions around cold chain expansion on food loss and emissions
- What are the effects of following expert recommendations on refrigeration coverage, efficiency, low-GWP refrigerants?

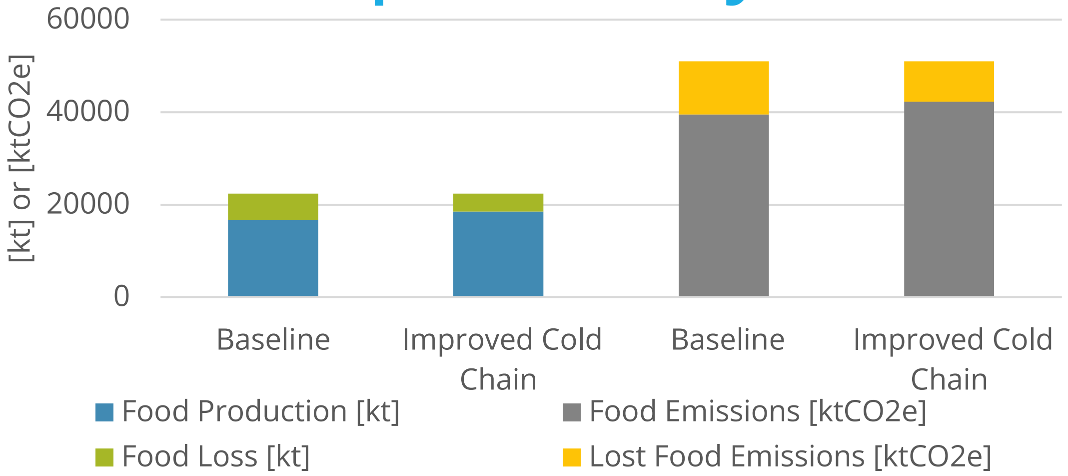
Modeling Roadmap



Will be improved with ongoing data collection efforts

Illustrative Example: Kenya

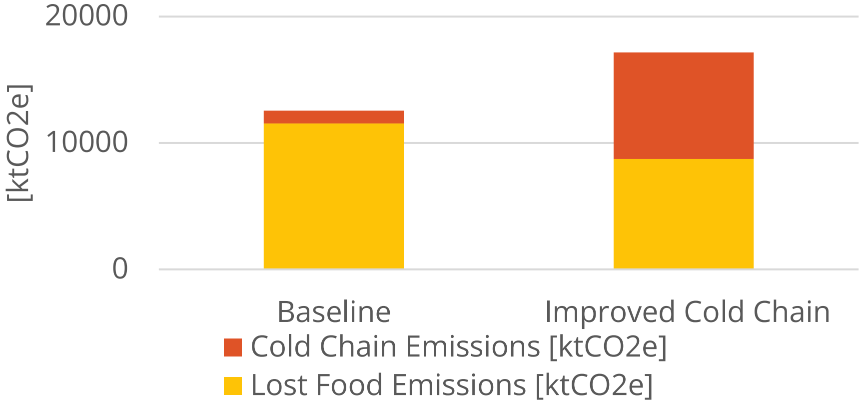
Improved Cold Chain:
32% less food loss
24% less emissions from lost food



<u>11% more food delivered for same production</u>

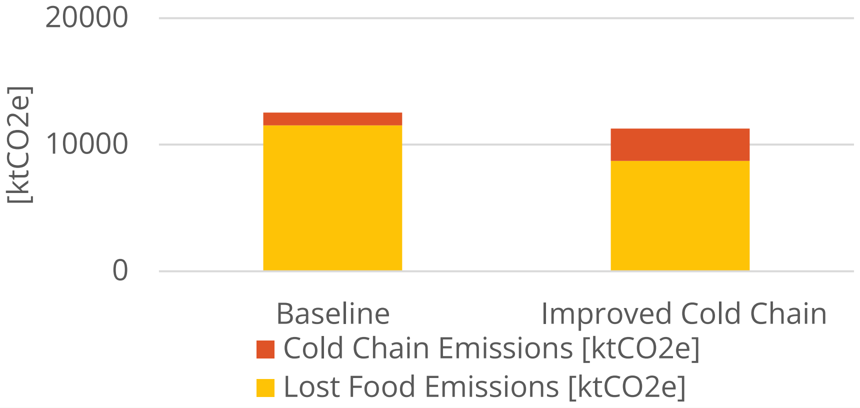
Less-sustainable expanded cold chain:

- 9x increase in domestic refrigerators (31M in nation of 50M)
- Maintain current high electricity emissions (0.5kgCO_2eq/kWh)



Sustainable expanded cold chain:

- 12M refrigerators (1 per household)
- Low GWP Refrigerants
- Planned electricity decarbonization (0.3kgCO_2eq/kWh)



Sustainable cold chain emits 7% less CO_2 per mass food delivered compared to current baseline cold chain

Towards a Sustainable Cold Chain Definition

Past work has always compared against existing developed cold chains, this is problematic because:

- Developed countries tend to have higher rates of consumer food waste
- Many developed countries may have more refrigeration equipment than optimal
- Existing products use legacy refrigerants with much higher GWP/ODP
- Electricity production is rapidly decarbonizing; dated values will significantly overestimate equipment emissions

When evaluating the impacts of cold chain expansion, we should compare with a cold chain that is *optimized for sustainability (not just copied from developed countries)* using expert recommendations for:

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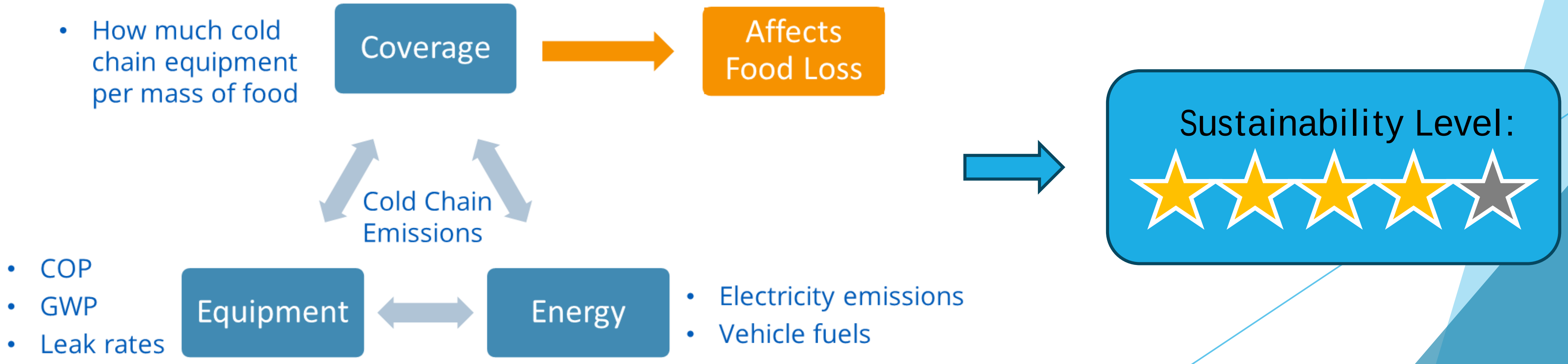
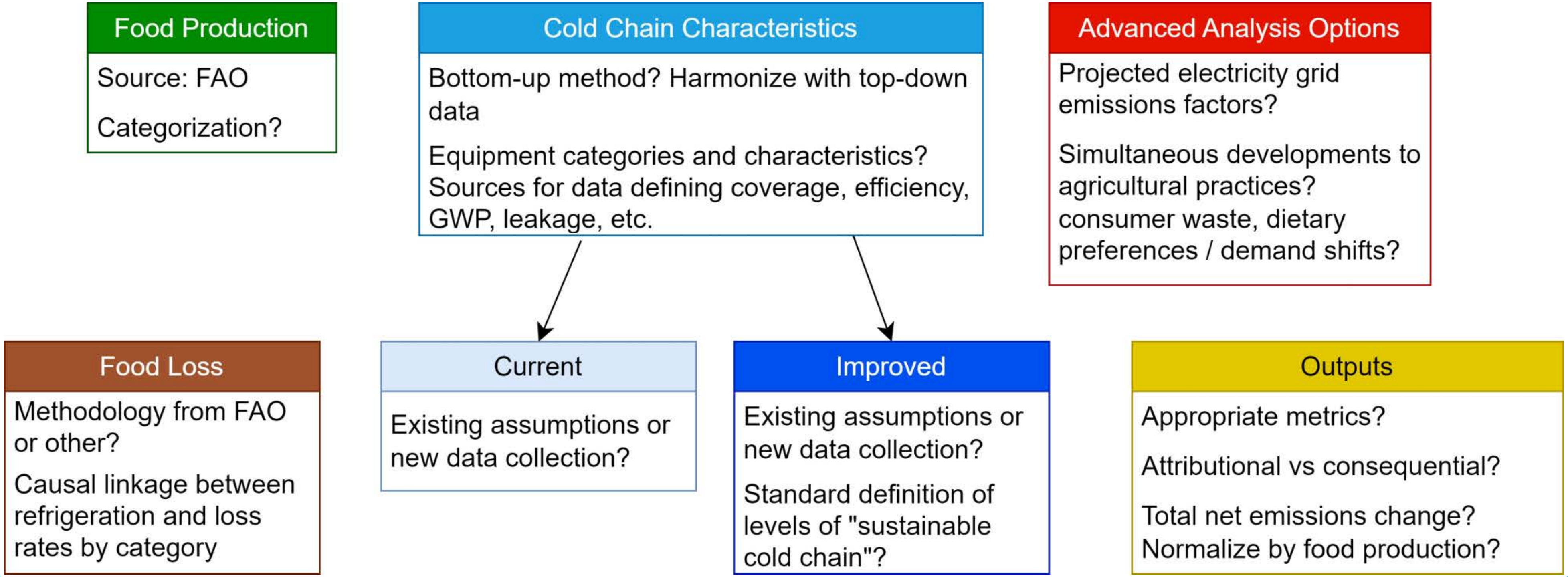


Path Towards Methodological Consensus

- Complex, interdisciplinary problem - requires contributions from experts from multiple fields to resolve open questions



Discussion and Conclusions

- The environmental impact of the future cold chain has the potential to be much lower than the systems of the past and present - modeling should be updated to reflect this
- Establishing a "standard" set of characteristics of a "sustainable cold chain" allows us to project future benefits of cold chain expansion with less reliance on current data or comparisons against other developed countries
- Reaching consensus on methods and metrics is essential to ensuring that the analysis delivers meaningful results - time is of the essence

We invite collaboration - Contact us!

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