Modelling the environmental impact of economic activity

Presentation in NETØK

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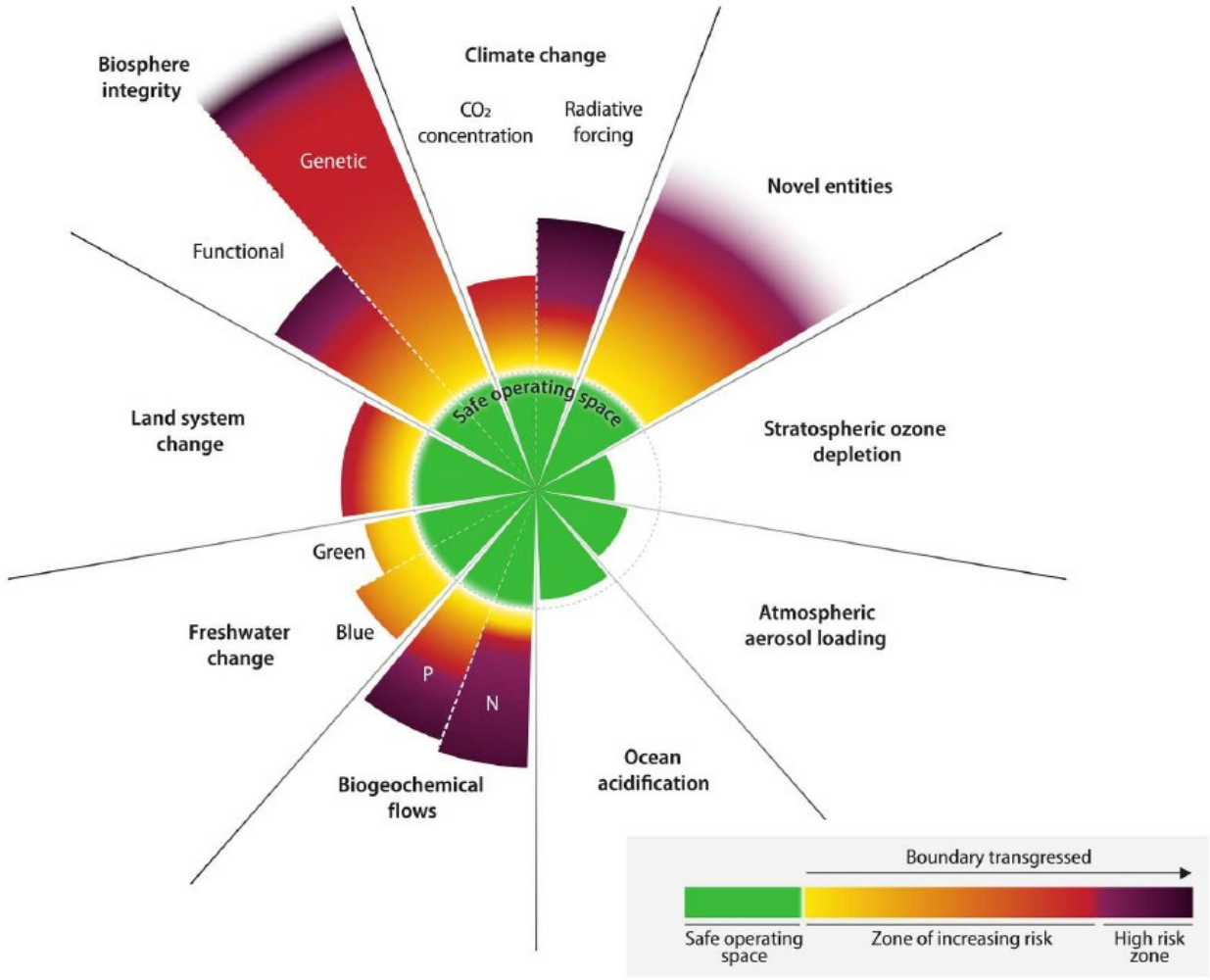
Agenda

- What are the environmental issues we need to address as economic modellers?
- How are we currently trying to address these issues in Denmark?
- How could our models be improved?

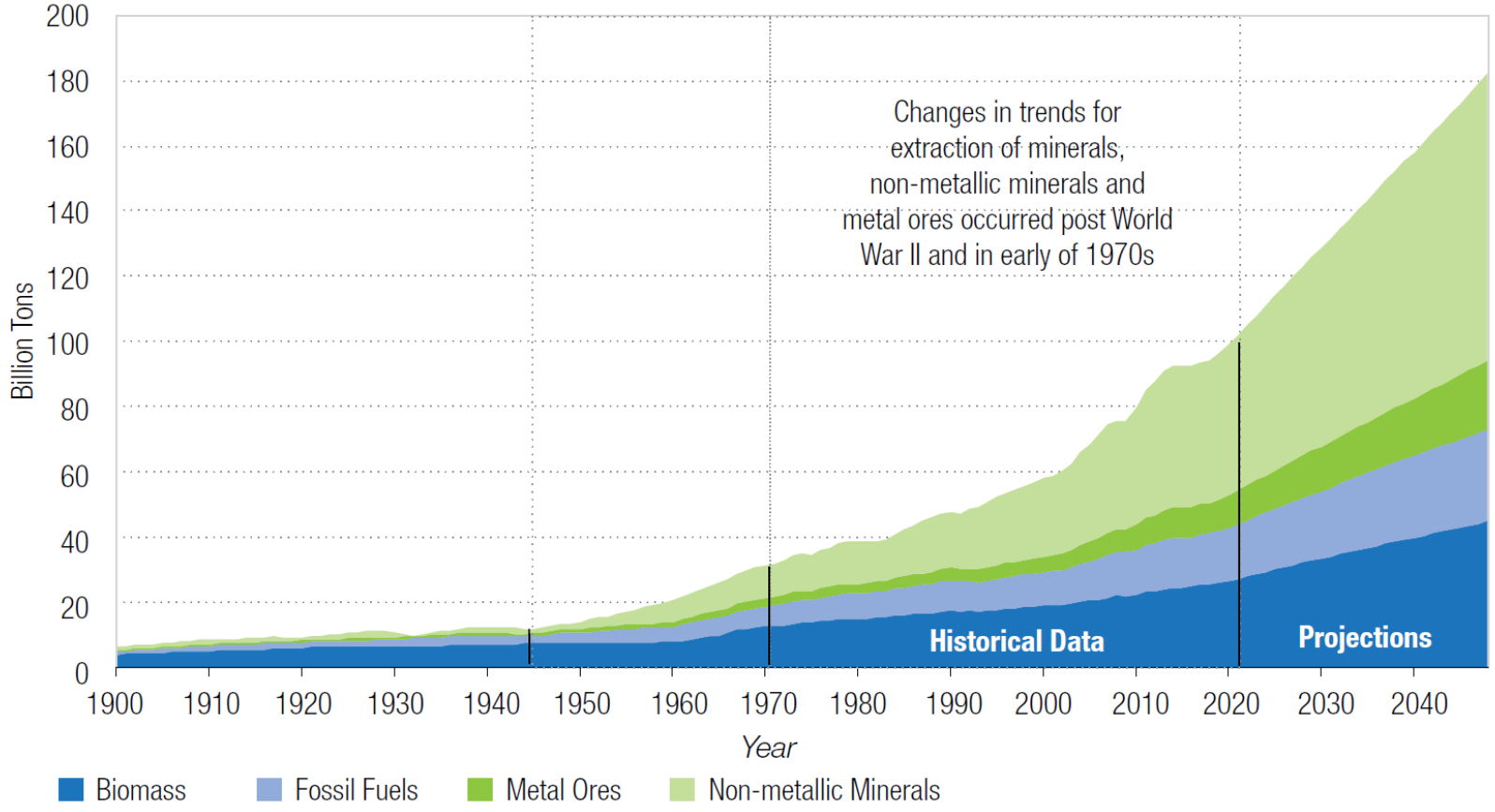
Background: A global environmental crisis with many dimensions



Source: Richardson et al. (2023).

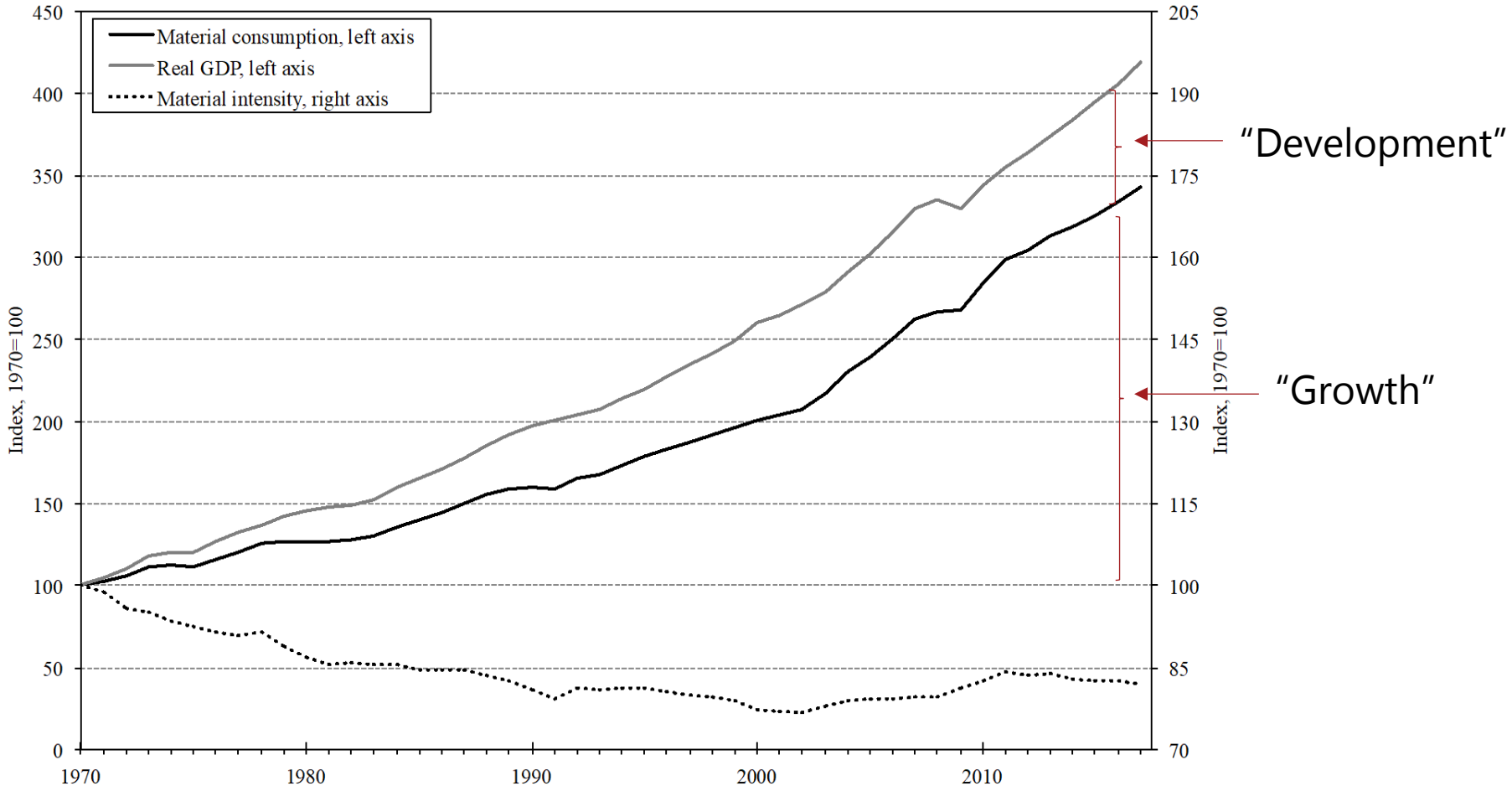
The source of the problem: The ever growing use of materials

FIGURE 1.2: HISTORICAL AND PROJECTED GLOBAL MATERIALS EXTRACTION BY RESOURCE



Source: European Commission (EC) Joint Research Center.

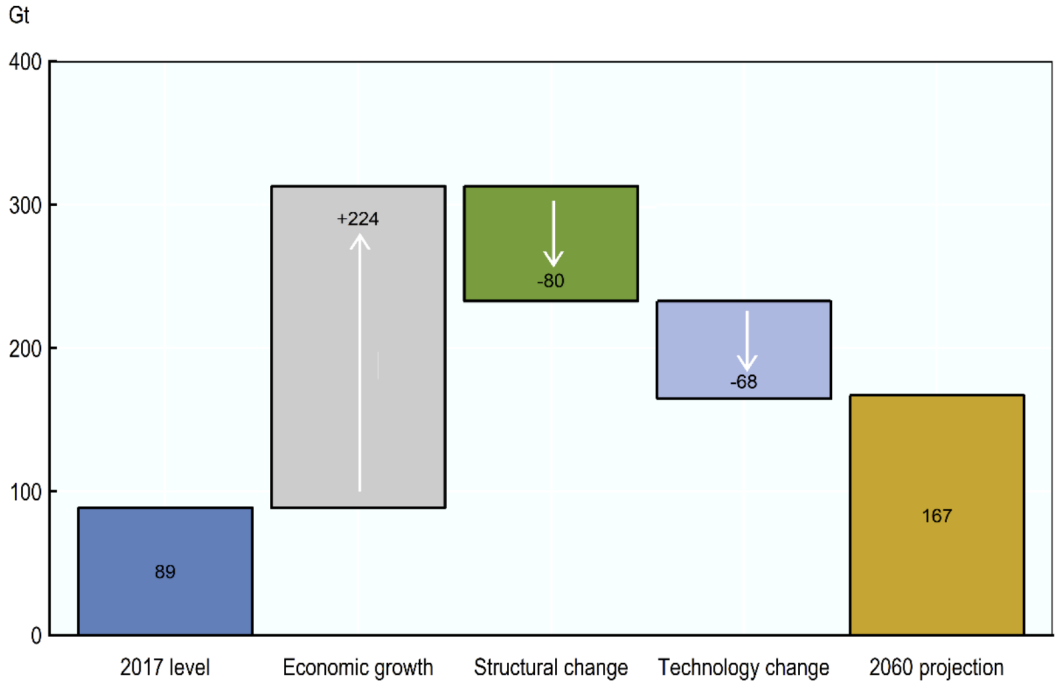
A lot of growth but little development: Global material consumption and GDP, 1970-2017



Source: UN IRP Global Material Flows Database and World Bank's World Development Indicators database.

It's not getting better: OECD forecast of global material use in a Business-As-Usual scenario

Decomposition of the increase of materials use between 2017 and 2060 in Gt



Note: The four bars read as follows (from left to right):
1. *Economic growth* represents a counterfactual projection in which materials use is assumed to grow at the same speed as GDP and thus in which the regional materials intensity of GDP stays constant.
2. *Structural change* identifies the contribution of sectoral shifts to reducing global materials use by differentiating sectoral growth rates.
3. *Technology change* identifies the contribution of technology improvements to reducing global materials use by differentiating growth rates of materials inputs to sectoral output.
4. The combined effects lead to the *Central baseline projected growth*.

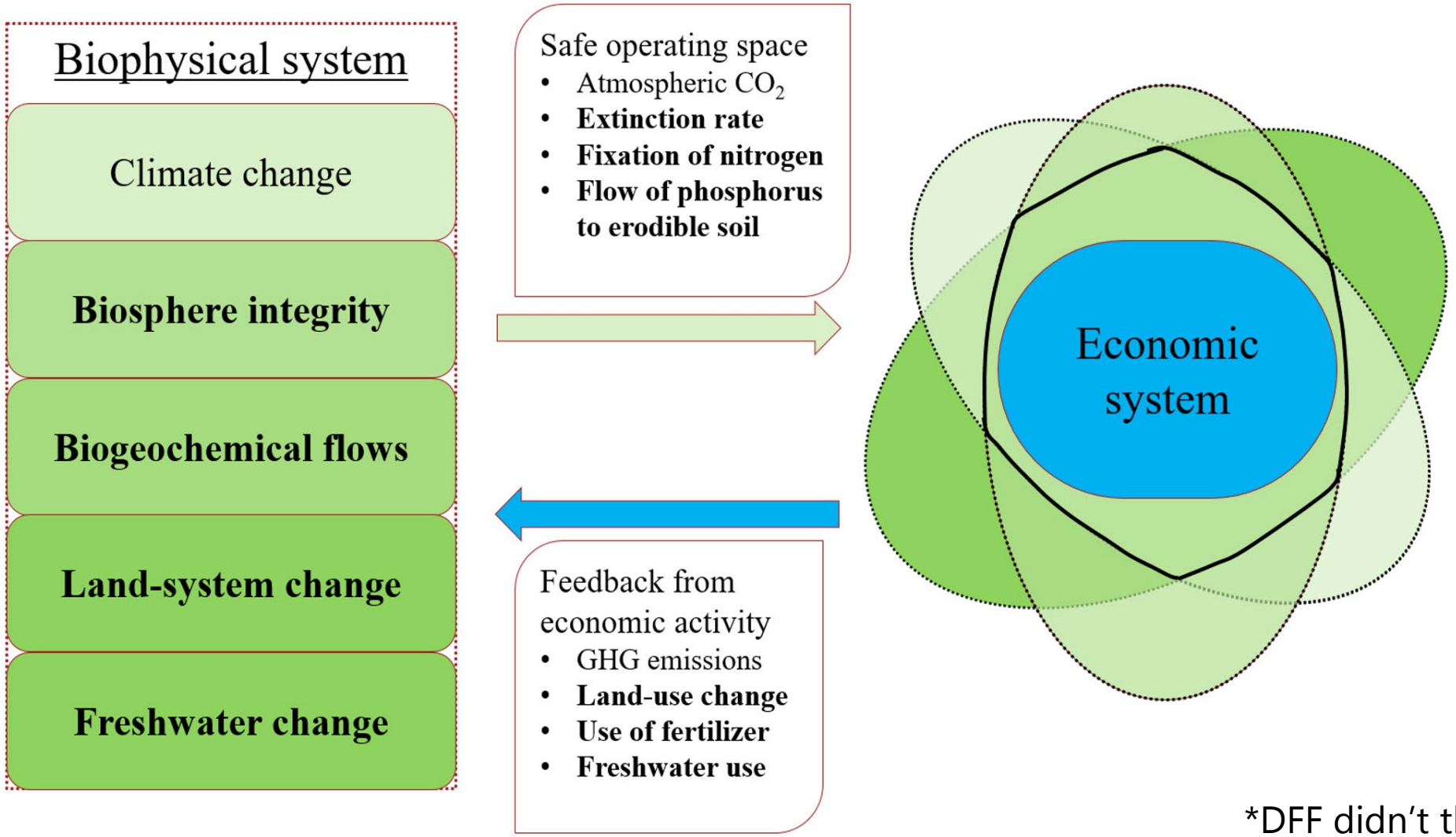
Source: OECD ENV-Linkages model.

Kilde: Global Material Resources Outlook to 2060. OECD 2019.

Material use is expected to grow from 89 Gt in 2017 to 187 Gt in 2060

OECD: "The strong increase in demand for materials implies that both primary and secondary materials use increase at roughly the same speed."

We need to build a new type of global Integrated Assessment models: Perhaps something like this?*



*DFF didn't think so!

From global to local:
The GreenREFORM model
of the Danish economy

GreenREFORM is Denmark's contribution to international modelling efforts

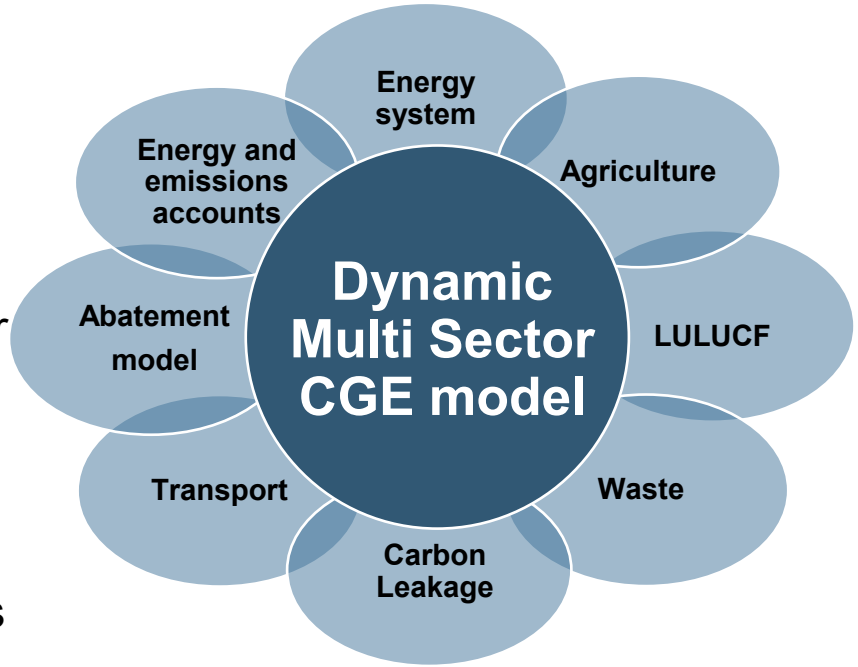
Coalition of Finance Ministers for Climate Action
Involves Finance Ministers from 90 countries.

Denmark and the USA ar3 co-leads on Helsinki Principle 4

"Take climate change into account in macroeconomic policy, fiscal planning, budgeting, public investment management, and procurement practices"

The GreenREFORM model system

- 60 sectors at national level with energy and emissions accounts
- Emissions of 11 different pollutants
- Yearly forecast towards 2100
- Detailed modeling of taxes, subsidies and other policy instruments
- Bottom-up integration of information on future technology
- Rich sub-models tailored for analysis of sectors particularly important for climate and the environment, which can be turned on and off as needed



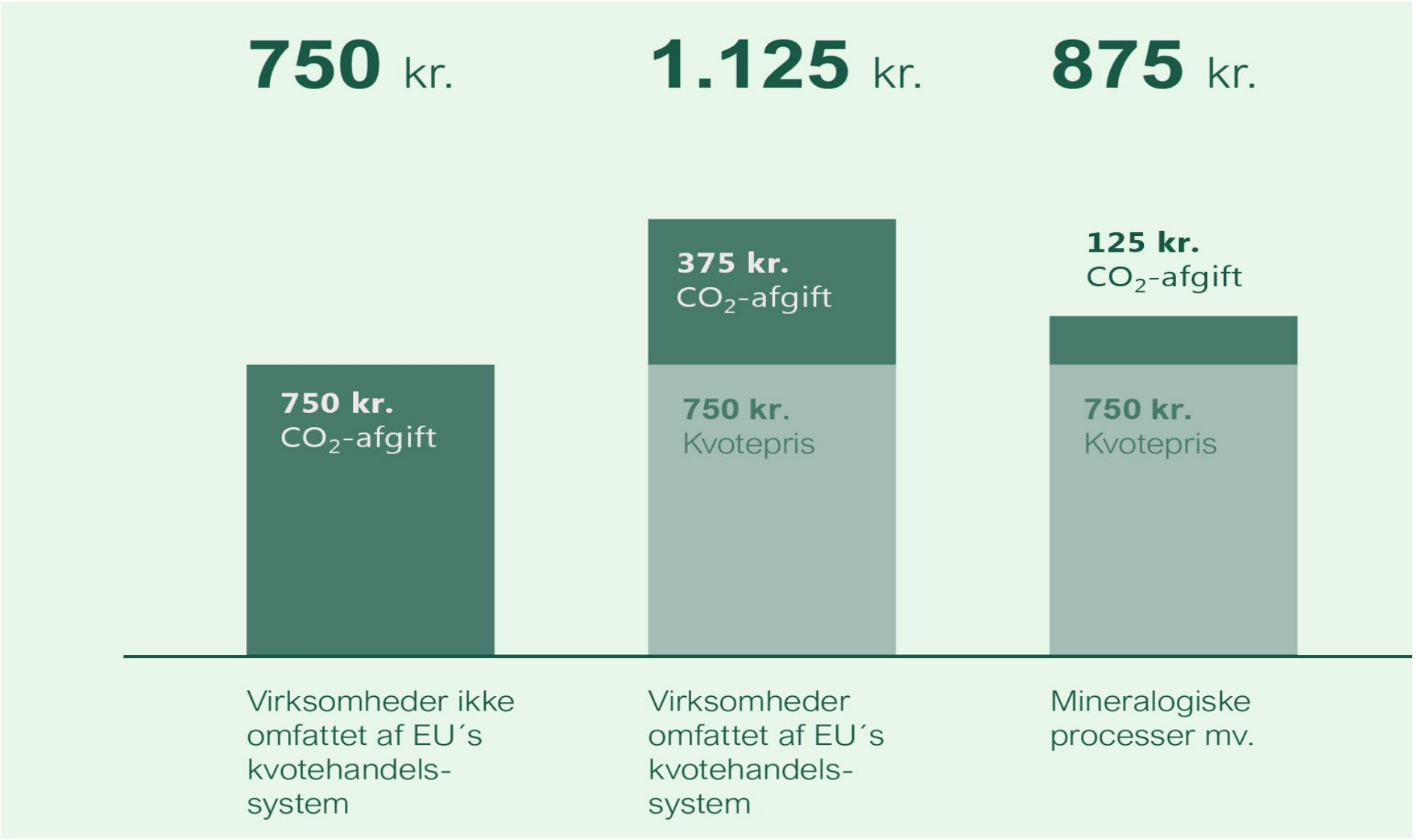
- Historical data by **Statistics Denmark**:
- Projection of energy use and emissions based from **The Danish Energy Agency**
- Macroeconomic projection from **The Danish Ministry of Finance (MAKRO)**
- Data regarding future technologies by **The ministry of Climate and Energy**

Macroeconomic features of GreenREFORM

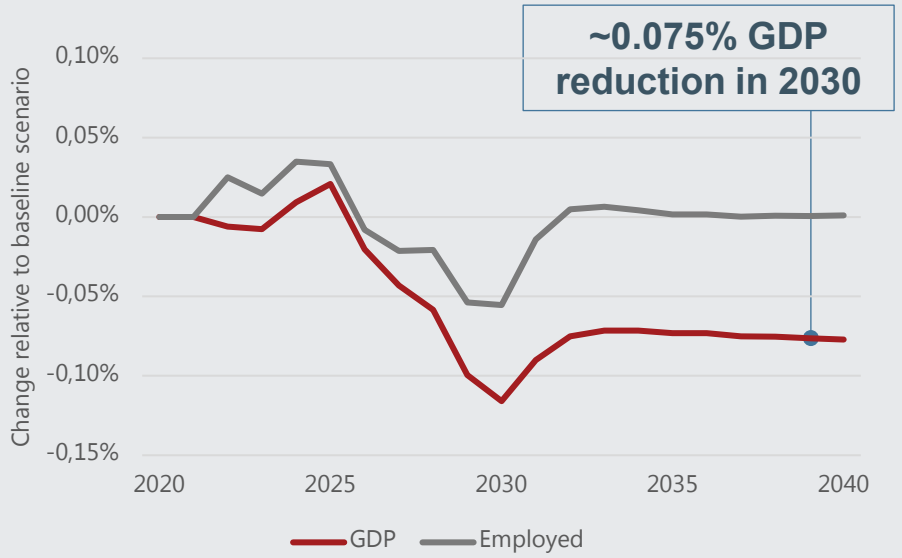
- Monopolistic competition in product markets, prices set as a mark-up over marginal costs
- Labour market with Philips curve implies sluggish wage adjustment – employment and output deviate from structural levels in the short and medium term
- Output determined by demand in the short term
- High degree of persistency in structural unemployment
- Forward looking behaviour in firm investments with frictions – it takes time to build up production capacity
- Households are partly credit-rationed/myopic and partly forward looking
- Key macroeconomic variables are calibrated against current forecast based on MAKRO – which seeks to describe the business cycle at a high level of sophistication.

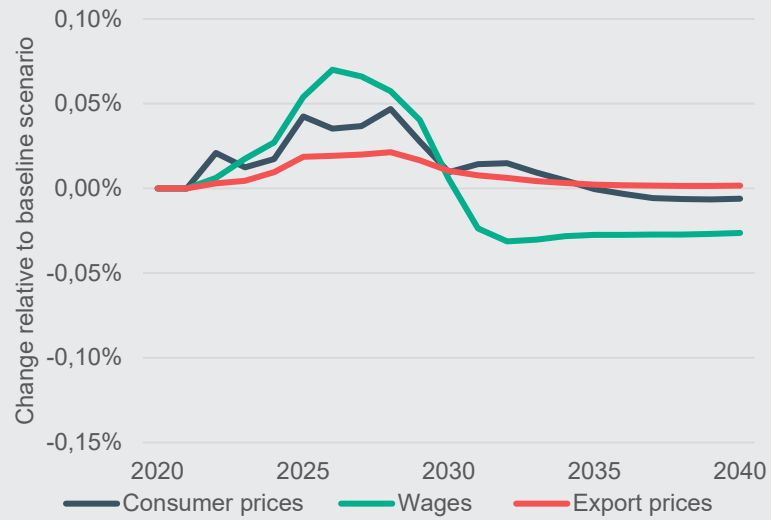
Example of an application of GreenREFORM: The Danish carbon tax on industry

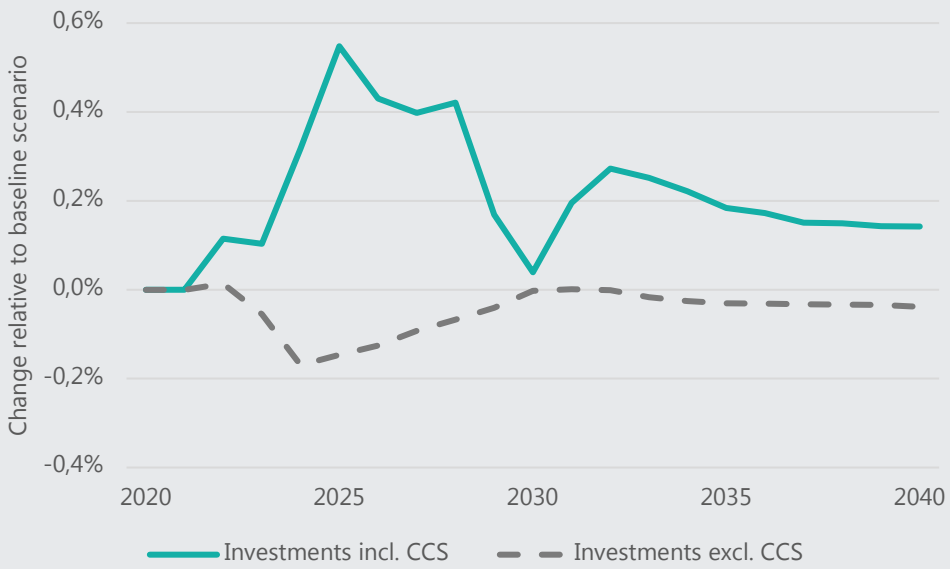
Political agreement of June 2022 on a green tax reform for industry and energy

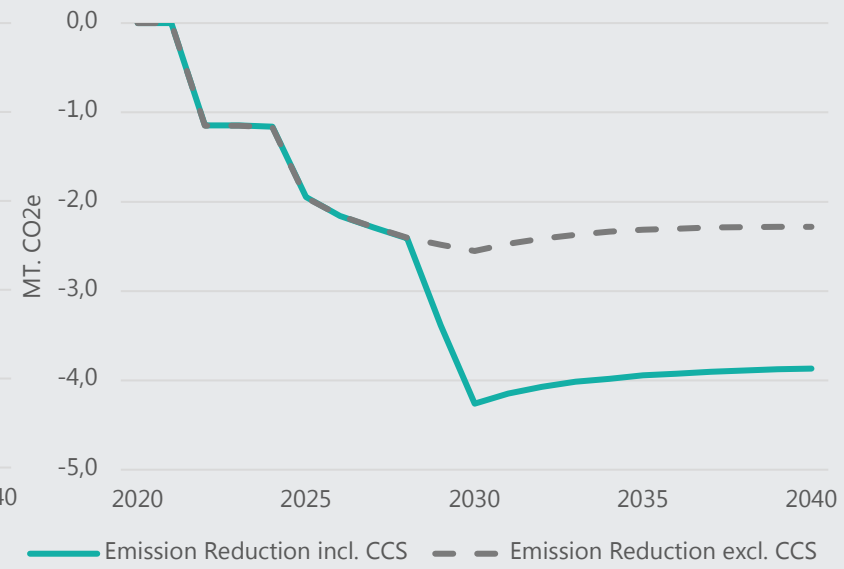


Modelling the effects of Denmark's 2022 green tax reform for industry and energy









Main results

- Reform introduces higher and more uniform carbon taxation in energy use and industry with tax rates up to 100 USD per ton (and 17 USD for mineralogical firms)
- Reduces long run economic activity, while employment rebounds to structural level
- Forward-looking firms adjust investments in advance (excl. CCS), expecting lower capital requirement in the future
- But this is more than offset by a boost in investments in CCS via a support scheme (incl. CCS)
- Wages fall due to loss of competitiveness to accommodate the return to structural employment

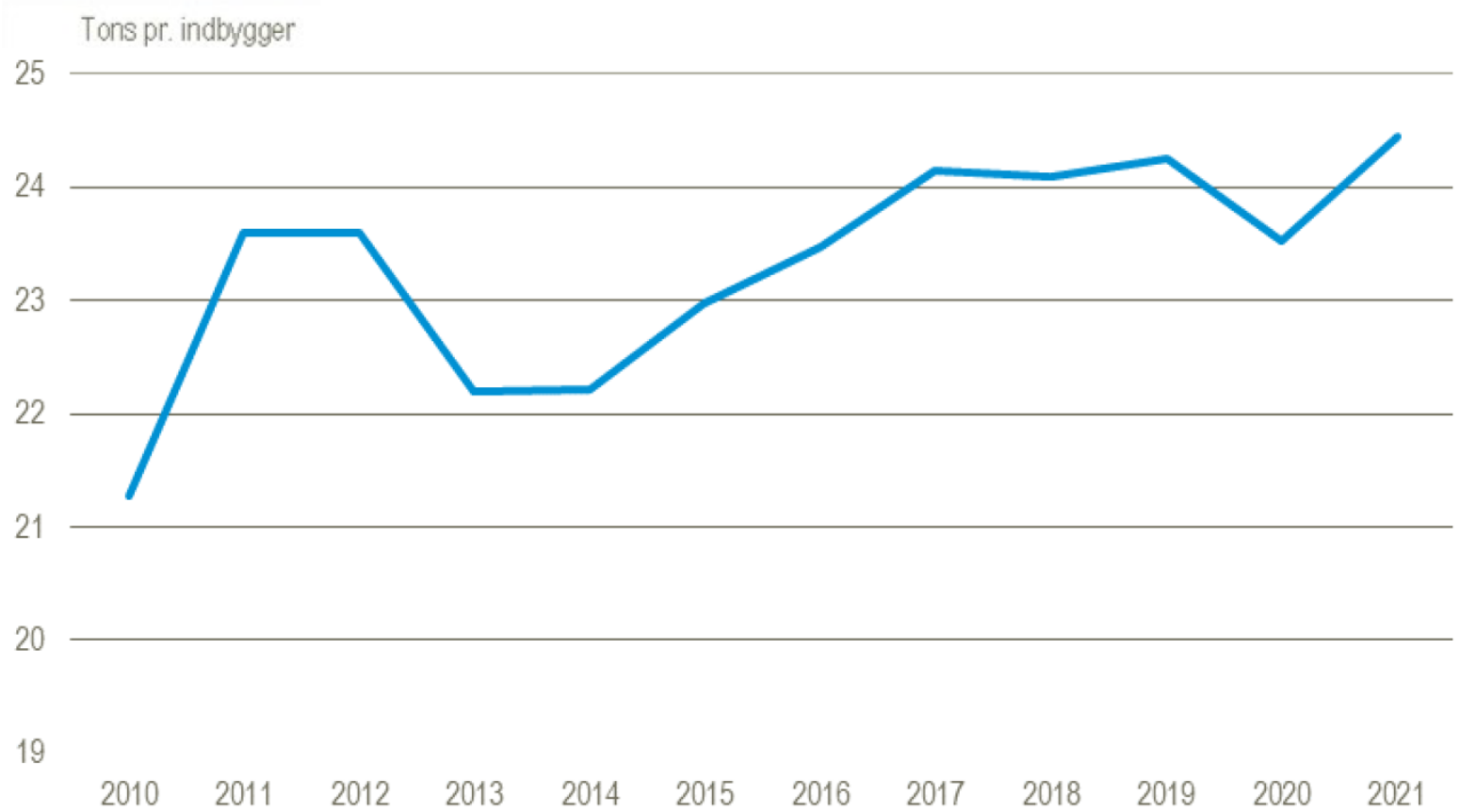
Plans for improvement of GreenREFORM (I): Material flows and circular economy

Background:

The need to include material flows

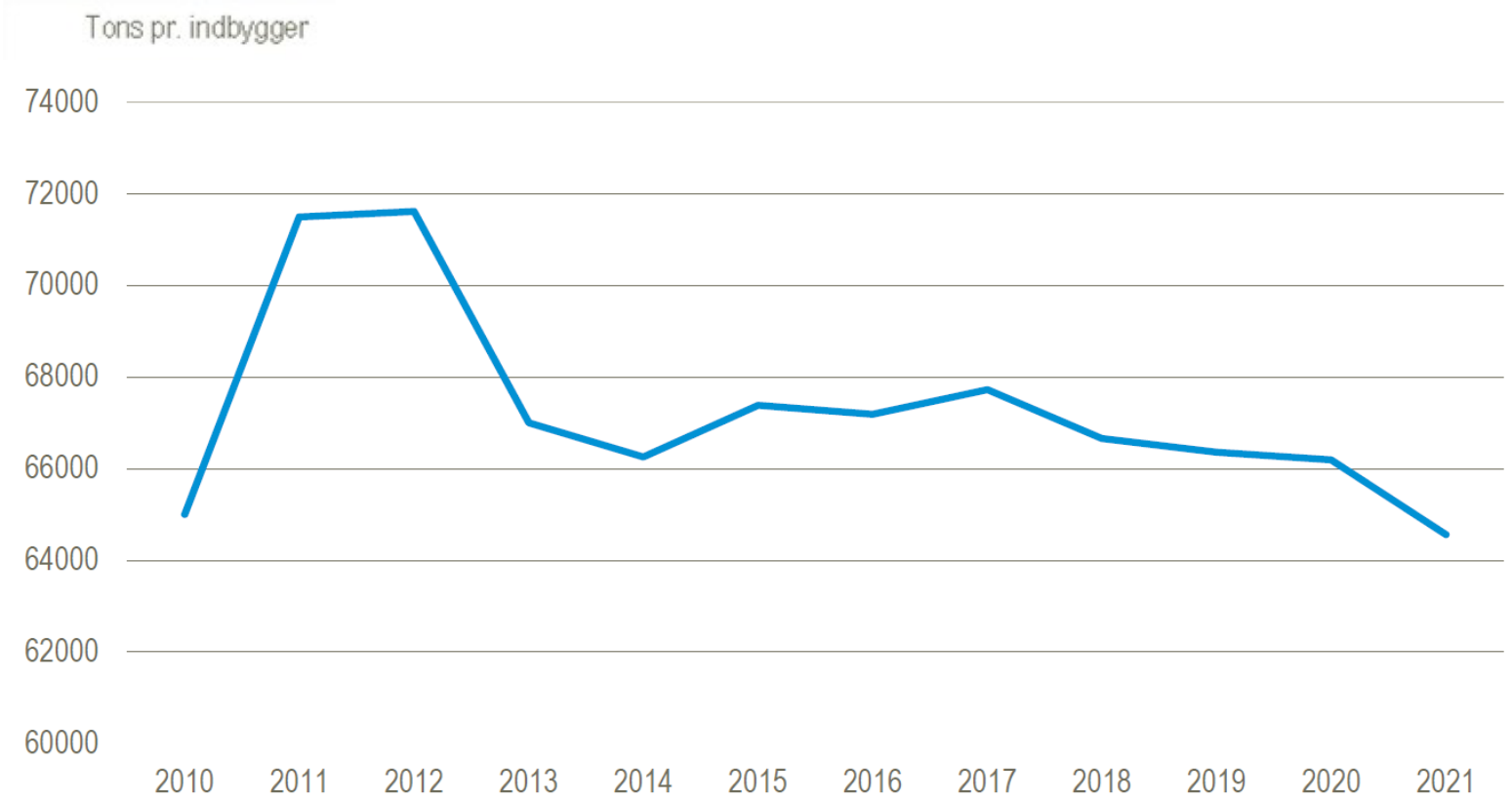
in economic models

Material use per capita in Denmark, 2010-2021



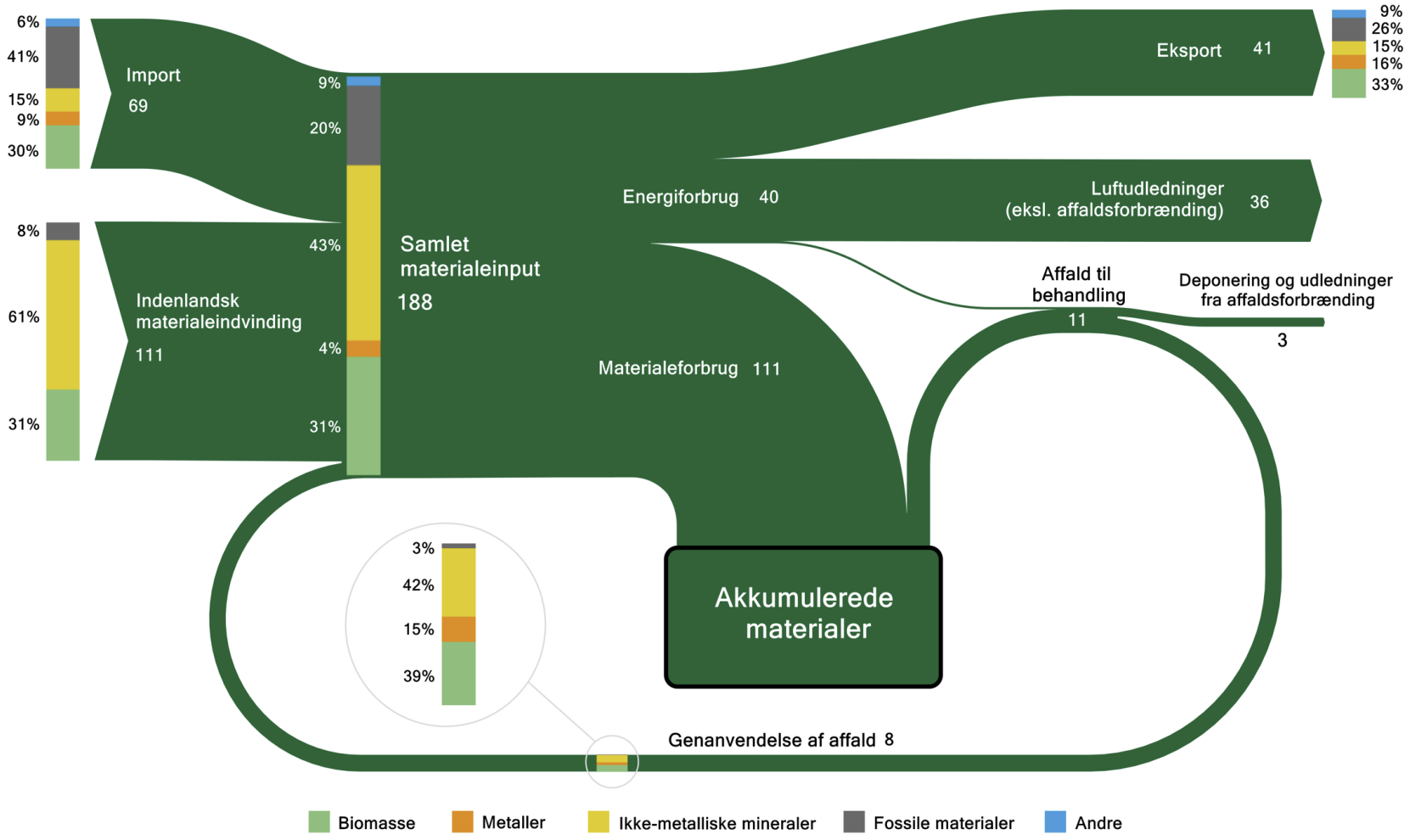
Figur 2.4: Dansk indenlandsk materialeanvendelse opgjort i tons pr. indbygger. 2010-2021. Denne indikator indgår i FN's verdensmål for bæredygtig udvikling (Sustainable development goals, SDG), nemlig delmål 12.2: Brug og håndter naturressourcer bæredygtigt. Kilde: www.statistikbanken.dk/sdg08042.

Resource productivity in Denmark, 2010-2021 (Real GDP/domestic material use)



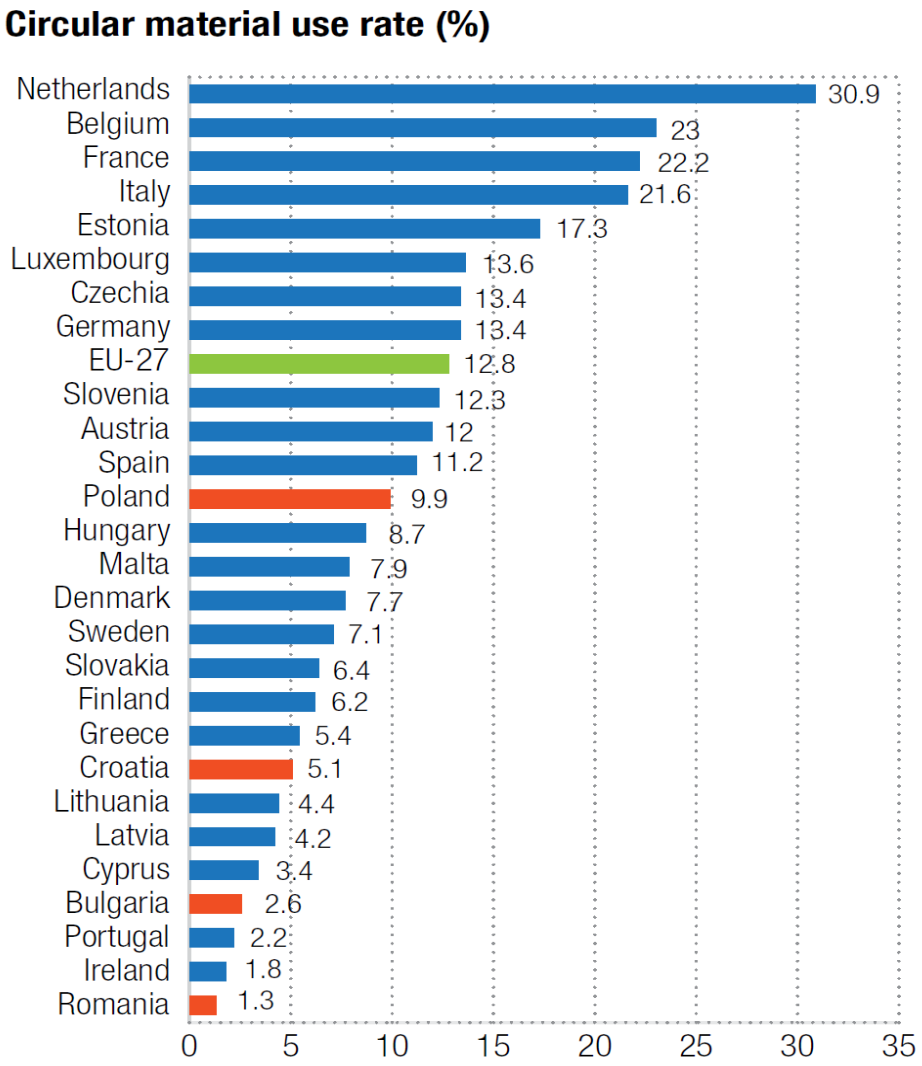
Figur 2.5: Dansk indenlandsk ressourceproduktivitet opgjort i tons pr. indbygger. 2010-2021. Denne indikator indgår i FN's verdensmål for bæredygtig udvikling (Sustainable development goals, SDG), nemlig delmål 12.2: Brug og håndter naturressourcer bæredygtigt. Kilde: www.statistikbanken.dk/sdg08042.

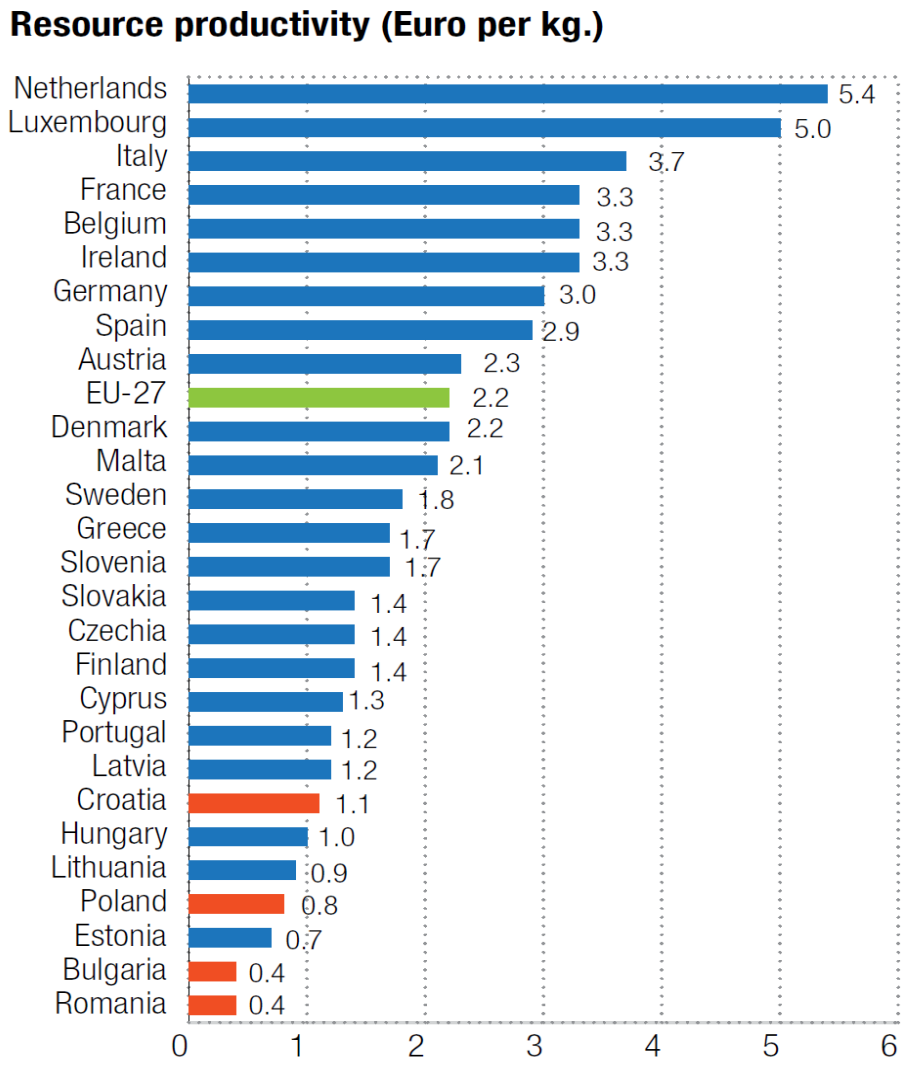
Material flows through the Danish economy in 2018 (million tonnes)



Recycling rate = 8/(188-41) = 5,4%. Source: Statistics Denmark.

Denmark is not good at reuse and recycling of materials



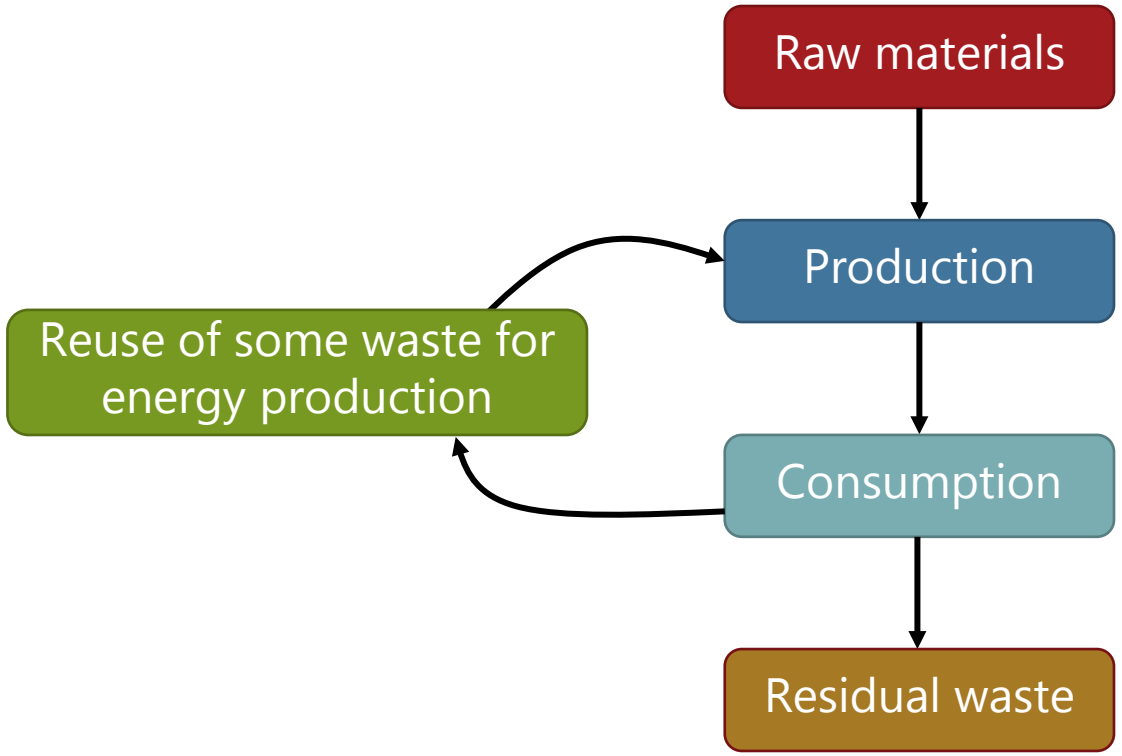


Source: Eurostat 2021b, 2022d.

The current modelling of waste generation and waste treatment in GreenREFORM

In its current form, GreenREFORM is mostly a model of a linear economy with some reuse of materials

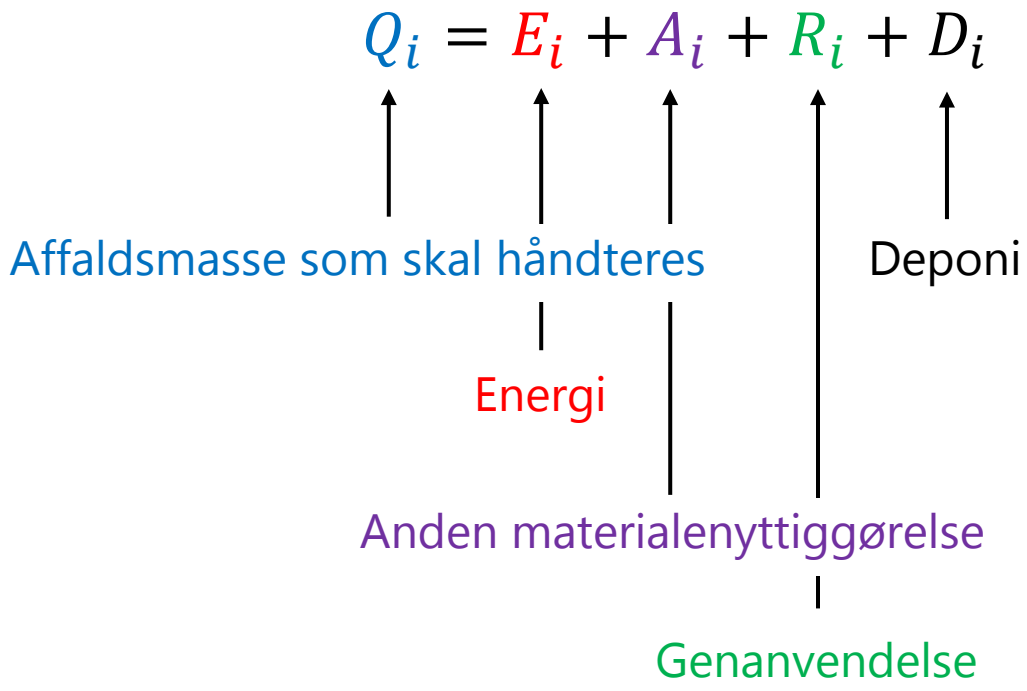
Linear economy with some reuse



Note: Some other forms of reuse are "hidden" in the model's input-output system

The waste treatment sector in GreenREFORM obeys the materials balance principle (I)

The First Law of Thermodynamics implies that the total energy/mass is constant in a closed system:



The waste treatment sector in GreenREFORM obeys the materials balance principle (II)

The First Law of Thermodynamics implies that the total energy/mass is constant in a closed system:

$$Q_i = E_i + A_i + R_i + D_i$$

$$R_i = \bar{R}_i + M_i + Q_i^R$$

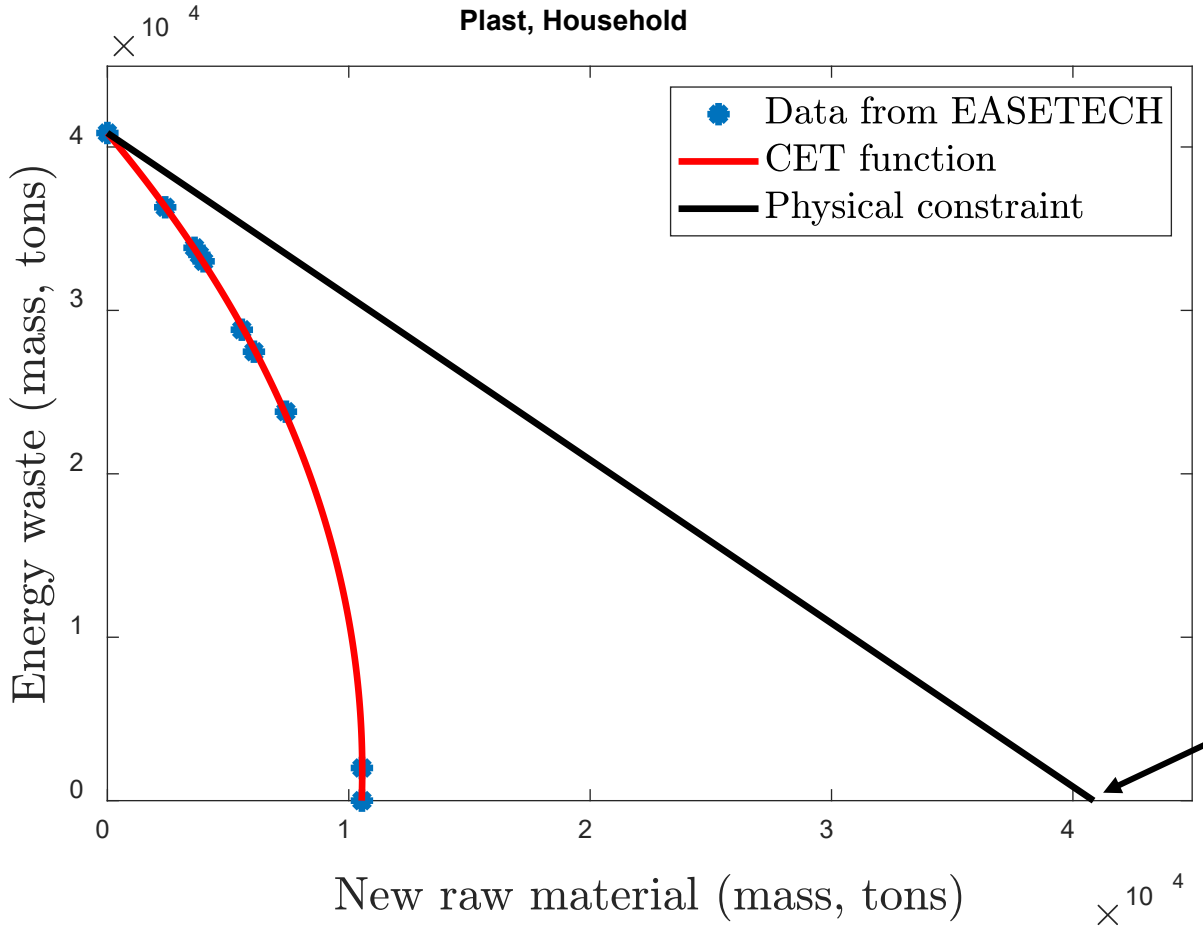
- R_i: Affald sendt til genanvendelse
- $\bar{R}_i$: Nye materialer
- M_i: Residualaffald
- Q_i^R: Emissioner

An example: Modelling the reuse of plastic in GreenREFORM (I)

Alternative uses of plastic waste: Reuse or burning as energy waste.

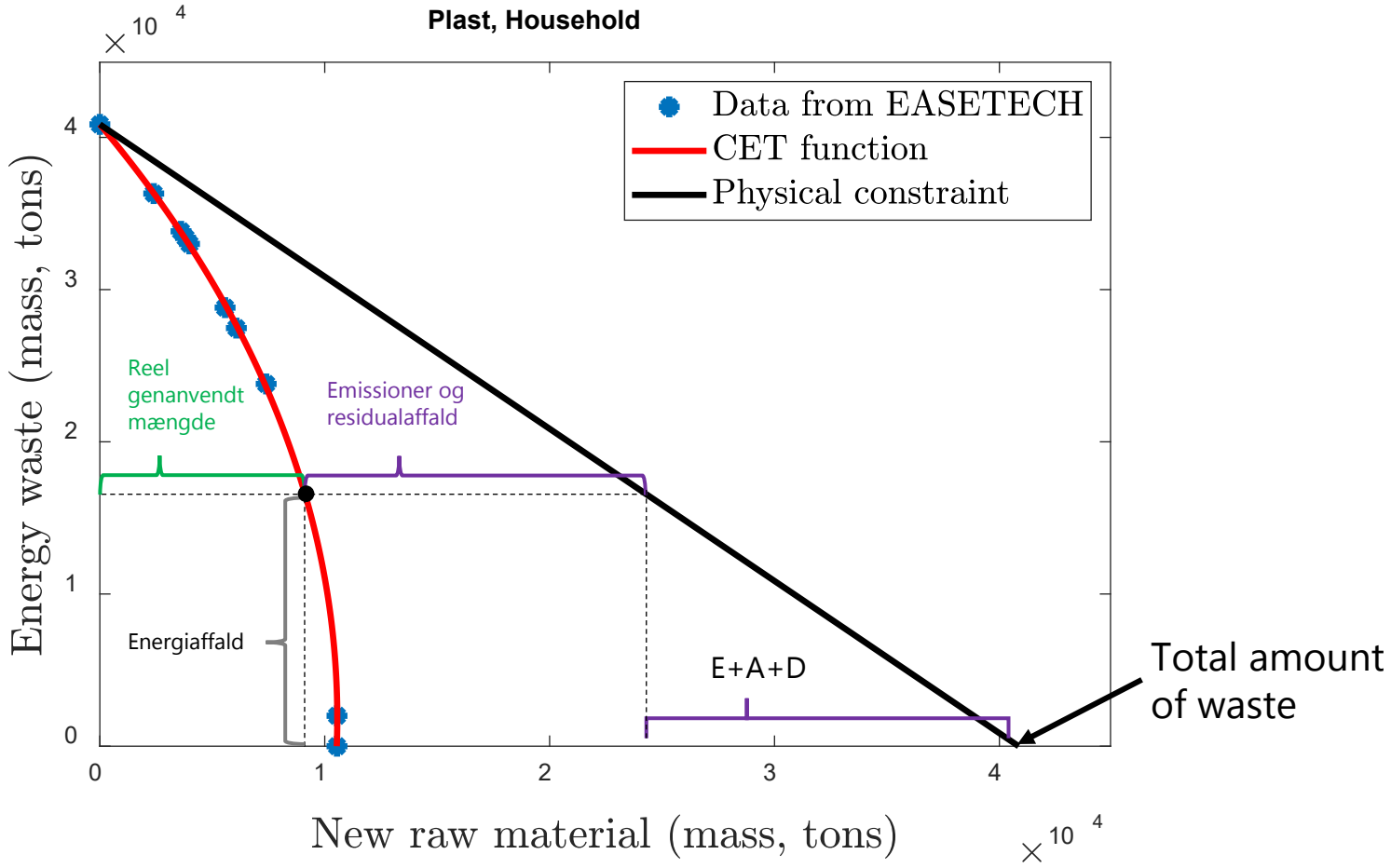
"Waste hierarchy": Possibilities for reuse must be exhausted before the waste is burned.

Note: The second law of thermodynamics helps to explain the CET function!



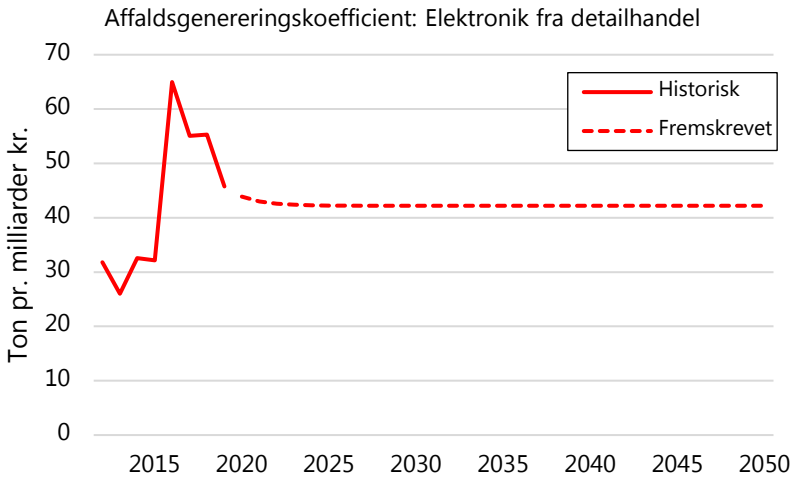
Note: The blue dots are engineering estimates of the technical potential for reuse, given current technologies

An example: Modelling the reuse of plastic in GreenREFORM (II)

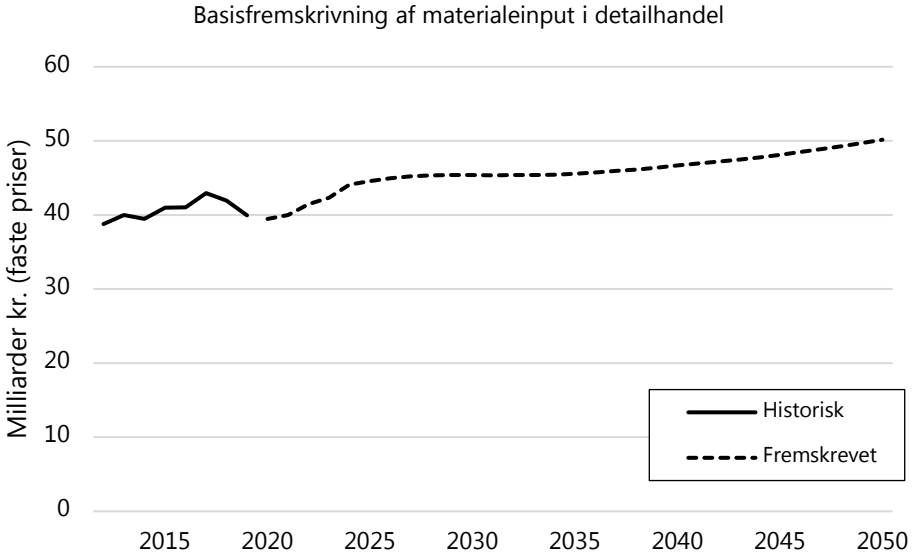


Forecasting waste generation in GreenREFORM: An example

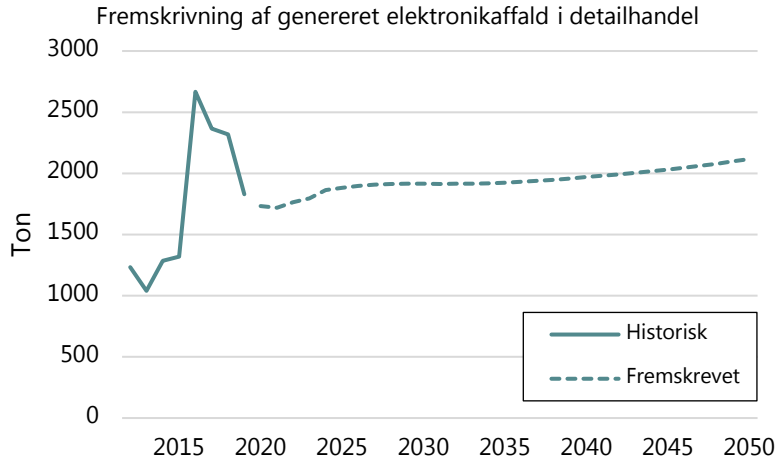
Step 1: Waste coefficients



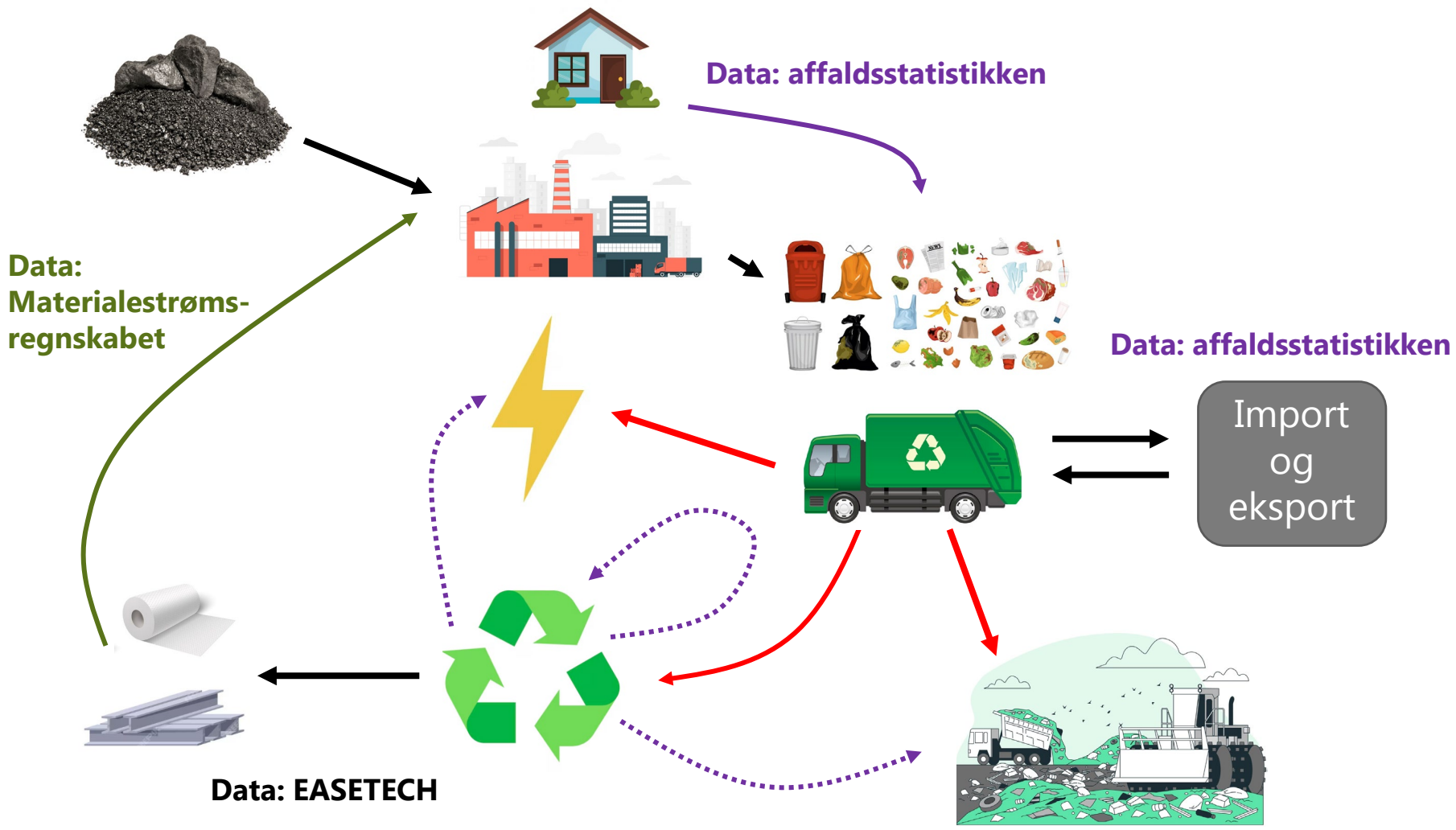
Step 2: Forecasting material input



Step 3: Forecasting waste generation



What we would like to do: Modelling all components of the circular economy



Plans for improvement of GreenREFORM (II): Modelling water pollution and biodiversity loss: The spatial dimension of pressures on the environment

Research plan (if someone will fund it!)

- **Background:** The pressure on the environment (e.g. water pollution) often depends on the location of the source of pollution and on land use

- **GreenREFORM** describes land use for agriculture and forestry at a rather aggregate level and does not have a spatial dimension

- The **TargetEcon** model contains a very detailed description of the spatial distribution of land use for crop production and forestry and of the spatial distribution of nitrate leakage to the water environment, but it does not include animal production and general equilibrium effects of environmental regulation

- By **coupling TargetEcon and GreenREFORM**, we would have a powerful tool for analyzing the economic and environmental effects of land use changes and other forms of regulation, e.g. land set aside for biodiversity protection