Modelling transition to low carbon economy with large scale DSGE model of Poland

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Part of the WB project „*Transition to a Low-Carbon Economy in Poland*”

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Top-down

↕

Bottom-up

ROCA model

Multi-sector, multi-region CGE

- structural change
- international feedbacks
- details of policy implementation (ETS/non-ETS, CDM)

MEMO model

Multi-sector, two-region DSGE

- endogenous growth
- structural change
- numerous policy simulations

MAC curve

Marginal abatement cost „models“

- details of technology options for a number of sectors (power, other energy-intensive industries, ttransport, buildings, waste)

Time horizon

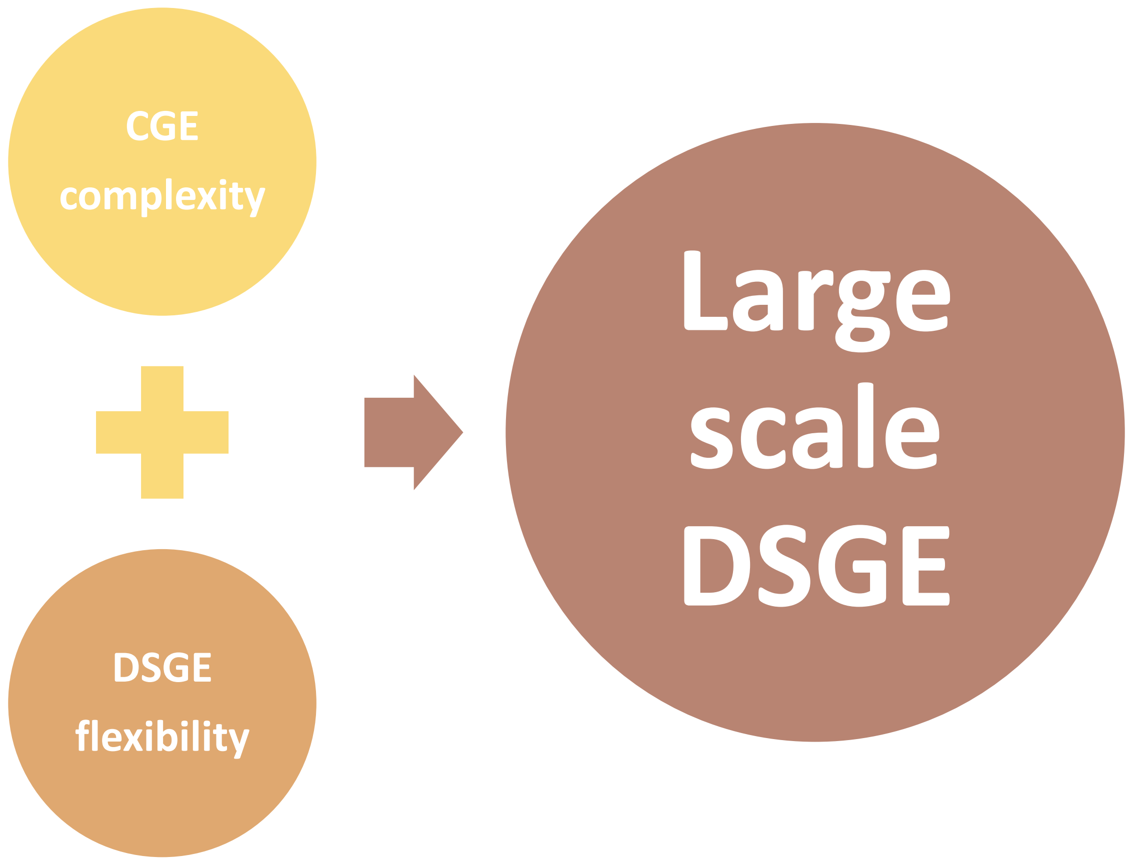
- ROCA model: 2020
- MEMO model: 2020 and 2030 ←
- MAC curve: Mainly 2030

Introduction (CGE vs DSGE)

- There is a broad literature on **CGE modeling** of environmental policies both on country and multi-country level,
- There are several **advantages of this approach** including
  - Tractability
  - Computability
  - Well established modeling tradition and availability of software (GAMS)
- At the same time however CGE models, although widely used in ex-ante policy assessment, do not belong to the contemporary **main stream macroeconomics** that concentrates rather on **DSGE (*Dynamic Stochastic General Equilibrium*)** type of models.

- DSGE modeling program probably forms **the most dynamic branch** of contemporary macroeconomics.
- It evolved as the **unification** of the **neo-classical RBC** (real business cycle) approach with the **neo-keynesian methodology** (macroeconomics of market frictions and imperfections) ;
- It has been widely used in **certain fields** of **macroeconomic policy** (monetary, fiscal) and recently started to expand on other fields;
- Due to computational issues DSGE models are typically **limited with respect to the number of variables** under consideration e.g. to the available disaggregation.

Our approach (LS - DSGE)



Main goals of our research

- Contribute to the **literature of the field** by:
  - constructing the **large scale multisector DSGE** model of the small open economy integrating both DSGE and CGE modeling features,
  - applying it to the **dynamic (year by year) macroeconomic impact assessment** of GHG abatement policy package,
  - computing the **macroeconomic version of MAC** (marginal abatement cost) **curve (MAC-ρ)** based on the broad set of individual mitigation levers,
- **Provide useful policy analysis** for the World Bank project *„Transition to a Low-Carbon Economy in Poland"*

Simulation toolbox

- Integrated simulation toolbox was constructed:
  1. **BAU module** (Business As Usuall):
     - Forms constraint for desired abatement levels in energy sectors (EU policy) – utilized later on by MIND module
  2. **MIND module** (Microeconomic Investment Decisions)
     - Computes optimal package of investment in energy generation and prepares information for MEMO model for each of over 120 individual mitigation levers including future CAPEX & OPEX
  3. DSGE **MEMO model** (MacroEconomic Mitigation Options)
     - In the Kalman-type filtering procedure conditional dynamic forecast of modeled variables is prepared

Simulation procedure

Stage 3: MEMO model (DSGE)

Utilize the MIND data to **prepare information** of future private/public expenditures, taxes, emissions etc

Take model solution, information, and **use Kalman smoother** procedure, and make **forecast**

Stage 2: MIND module

Take micro data (McKinsey **)** for **>120 different mitigation levers**

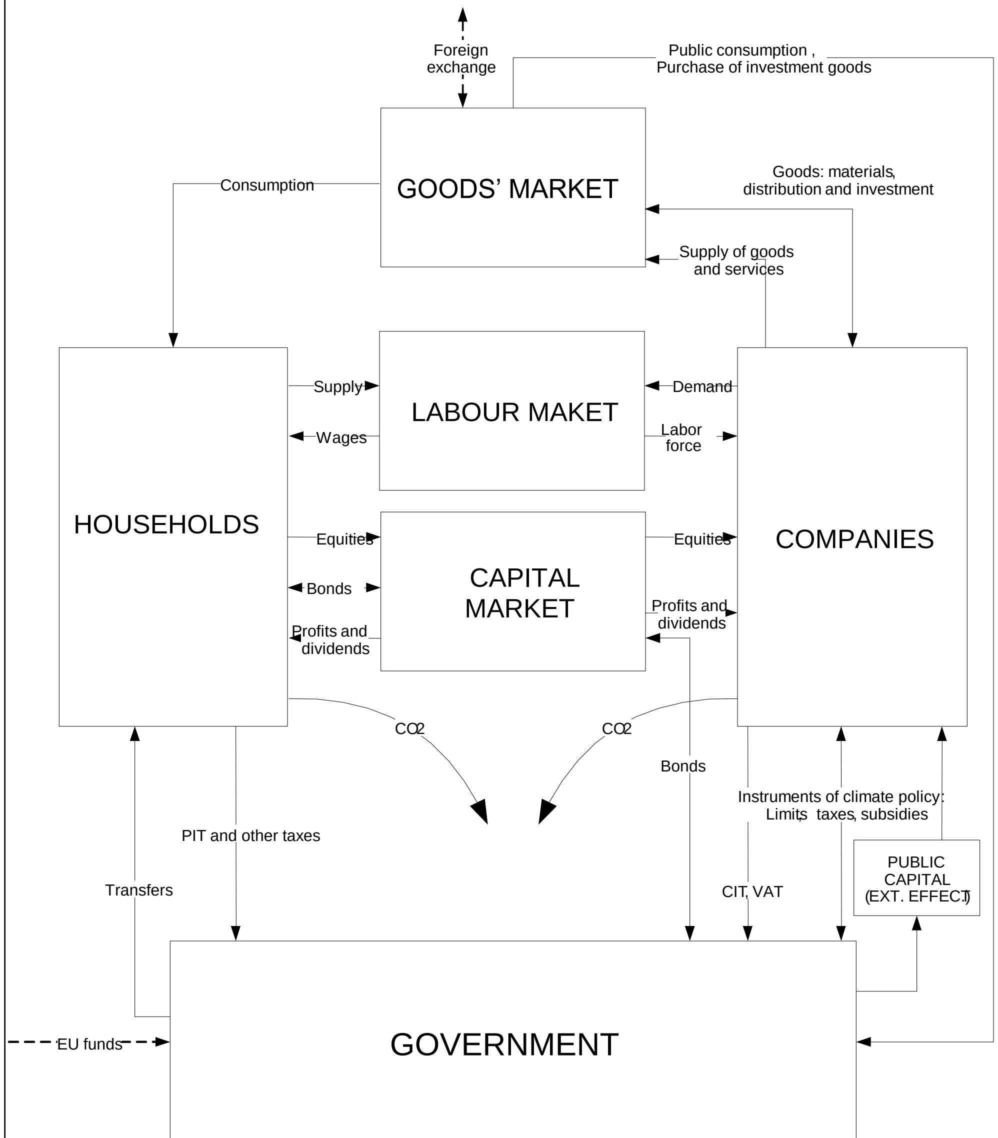
Calculate abatement, costs, gov subsidy, find the **optimal package**

Stage 1: BAU module

Take data on GDP, energy consumption, GHG emissions etc. for as many countries and periods as possible

Estimate **econometrically convergence rates** and apply them to individual countries/sectors – form BAU

IBS – MEMO model structure (1)



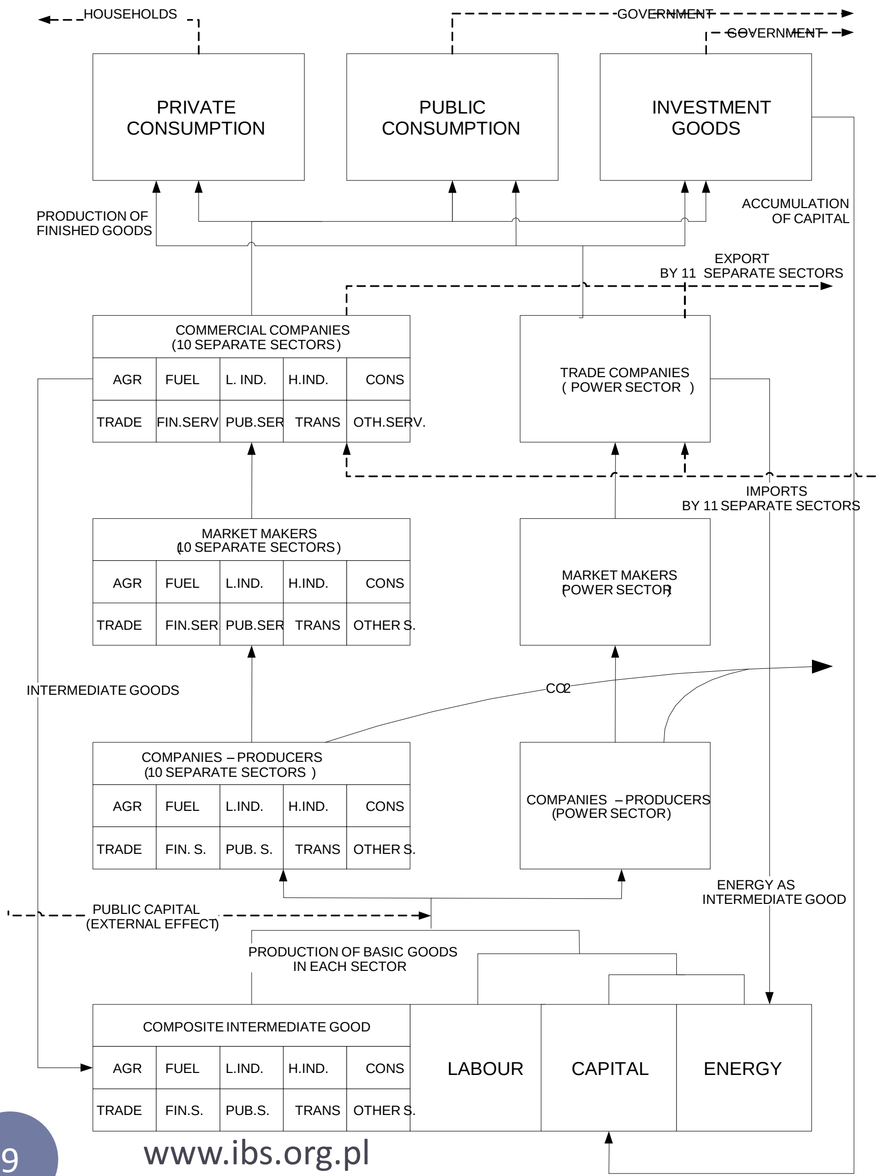
Model is composed of interlinked segments:

- Households
- Companies
- Markets: labor, capital and goods
- State

Model includes active Government:

- Imposes taxes and spends budgetary resources
  - CIT, PIT, VAT and other taxes (property taxation)
- Government spending include both public consumption and investments

IBS – MEMO model structure (2)



Production process is of multi-stage nature:

- Production of basic goods from means of production (energy, capital, labor, materials)
- Pricing
- Foreign exchange of goods (endogenous definition of exports and imports sizes)
- Production of aggregate sectoral goods
- Production of final products
- Purchase of final products by economic agents (firms, households, government)
- Full 11 sector IO table is incorporated

IBS MEMO model features (1)

It is a DSGE model…

- of **large scale** – over 2000 variables (typicaly for DSGE less than 200)
- of an **open economy**, trading goods with other countries (UE-26)
- **multi-sector** – there are 11 distinctive sectors recognized
  - Agriculture and food industry,
  - Light industry, **heavy industry, mining and fuels**, **energy sector,** construction
  - Commerce, transport, financial services, public services, other services.

Special care was devoted to the real side of the economy…

- Imperfect (**non-Walrasian**) labor market, where both seeking a job and finding employees is expensive, wages are negotiated and unhealthy unemployment exists,
- A rich **tax structure** (VAT, PIT, CIT etc) and rich expenditures structure (public consumption, public investment, transfers) of the public sector,
- **Production structure** following the KLEMS standard (K - capital , L – labor, E – energy, M – materials) – full **Input Output table** included

IBS MEMO model features (2)

The model was calibrated for actual data

- The most **recent available data** on Polish economy was used
- Calibration of only a **small number of parameters requires relying on literature**
- Model is capable to **mimic cyclical properties** of the data with **only 4 shocks**

	σ(GDP_t,X_t)		ρ (GDP_t,X_t)		ρ (X_t,X_{t-1})	
	Model	**Data**	**Model**	**Data**	**Model**	**Data**
CA_{t}	0.24	0.87	-0.74	-0.73	0.92	0.93
C^E_{t}	0.53	0.65	0.84	0.69	0.9	0.95
G^E_{t}	0.62	0.62	0.39	0.39	0.92	0.9
INV^E_{t}	4.76	6.33	0.99	0.94	0.93	0.95
EX_{t}	0.95	3.22	0.92	0.63	0.91	0.83
IM_{t}	1.42	4.5	0.99	0.82	0.92	0.91
q^f_{t}	0.54	5.05	0.71	-0.16	0.91	0.93
N_{t}	0.97	1.16	0.71	0.72	0.93	0.97
UR_{t}	6.99	7.94	-0.4	-0.66	0.84	0.95
W_{t}	0.63	2.39	0.12	0.14	0.91	0.84
DEM^f_{t}	0.86	0.86	0.7	0.71	0.92	0.92

Simulation procedure (2)

- Simulations were made separately for individual mitigation levers (>120 alternatives) forming together the entire potential GHG abatement package for Poland;
- For each lever the projected **private CAPEX & OPEX** (size and economic features), **efficiency/emission gains** and **government subsidies** were calculated,
- Projects were combined in 7 subpackages in order to simplify analysis but also because of their economic nature;
- Four government closures were considered (VAT, PIT, G, T);

Simulations (Stage 1 - BAU)

BAU module

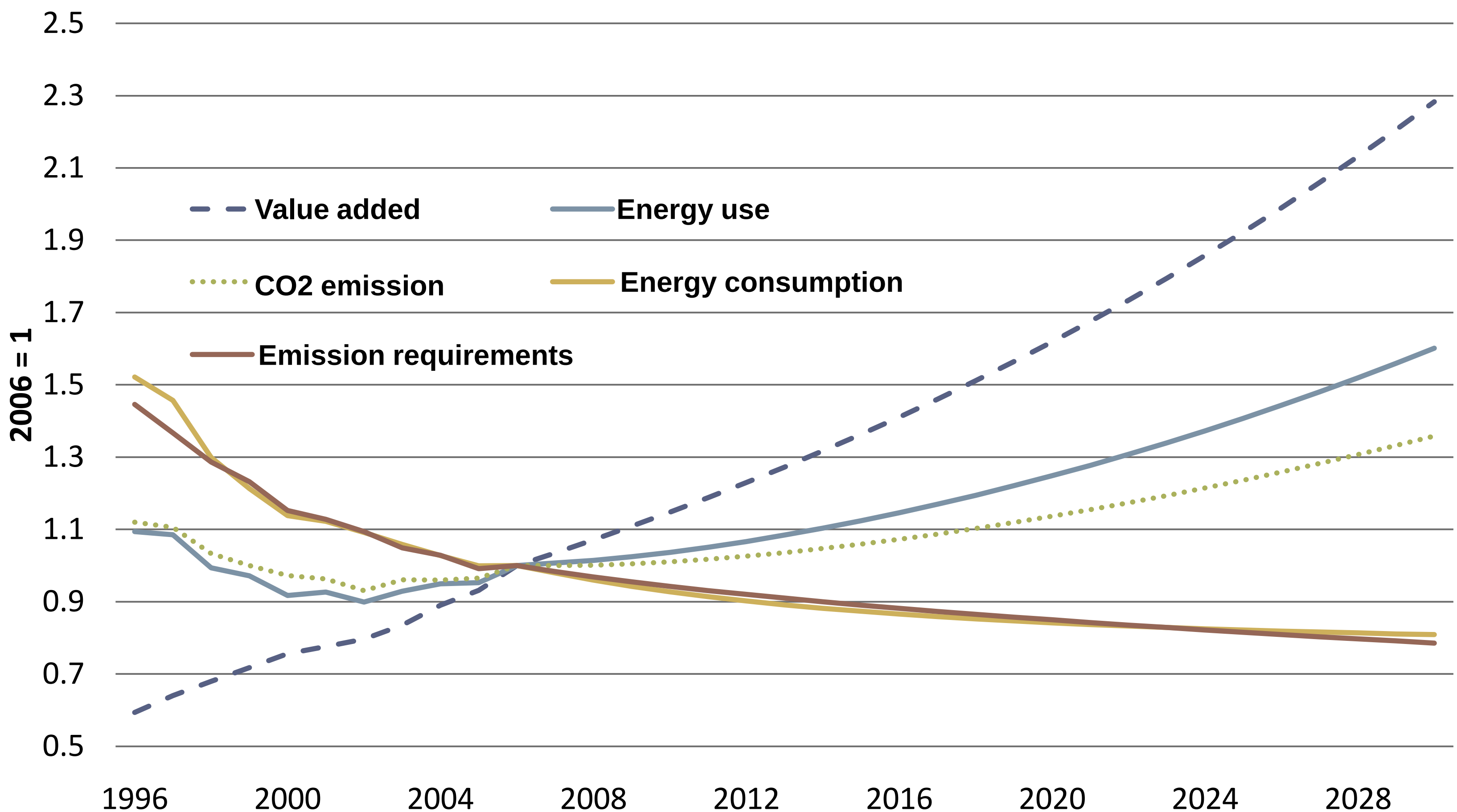
- Base case scenarios based on data
- Econometric analysis of convergence
- Base case scenario of added value, energy and CO_2 emissions in Poland and EU

- Building own reference scenario (BAU) pertaining to 11 sectors recognized in the model,
- Use of econometric convergence analysis within the EU
- Basing on EUROSTAT data
- Comparing results to aggregated McKinsey scenario

EUROSTAT data

- **21 EU countries, including Poland**
- **7-11 economy sectors**
- **Years 1996 - 2006**

BAU – main aggregates



Simulations (Stage 2 - MIND)

MIND module

NPV of energy investments

Multi-criterion optimization

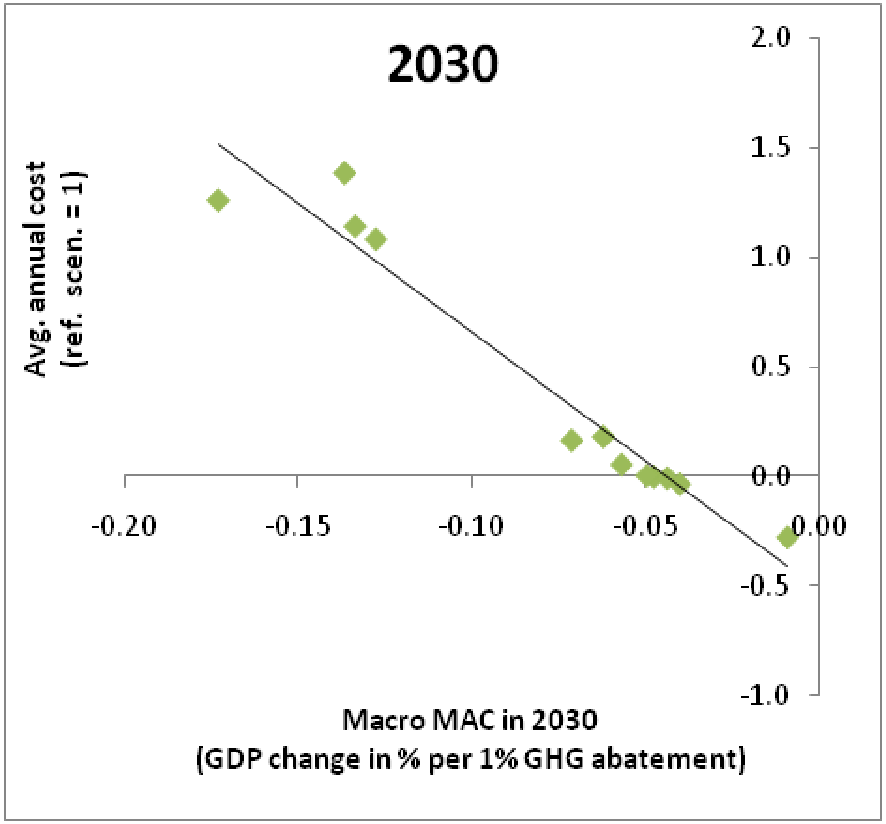
Optimum investment packages reducing emissions

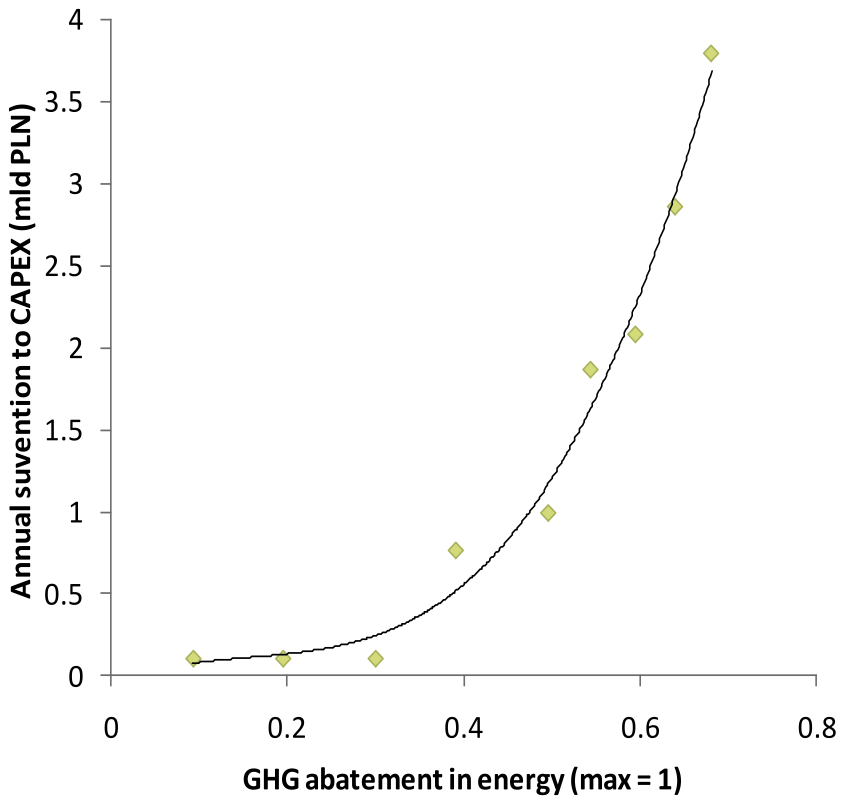
- More general, but similar methodology to McKinsey, based on NPV analysis
- Assessment of optimum and/or discretionary packages (of the least cost and best achivable abatement) at given constraints, e.g.
  - Including mostly the energy sector
  - Selected energy technologies
  - Assuming a specific level of reduction in individual sectors
- Rework, interpretation and verification of original McKinsey micro data

Input: McKinsey data

- **Energy**
- **Other sectors**

MIND aggregated results





Simulations (3)

MEMO model

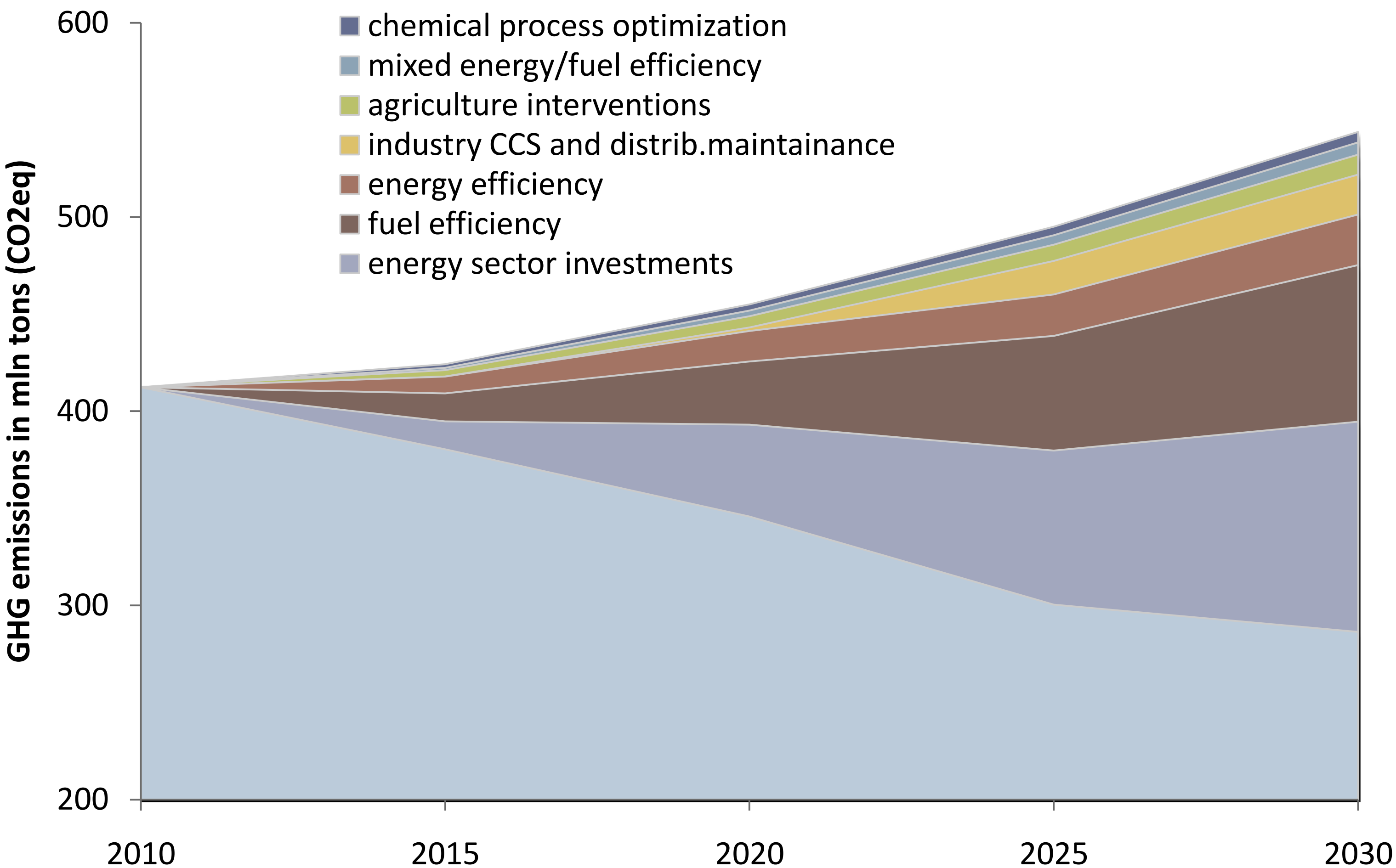
- Multi-sector structural model, DSGE type
- Numeric experiments using the model
- Filtered (conditional) macroeconomic forecasts

- Year by year assessment of macroeconomic impacts of climate policy by the year 2030
  - Impact on GDP, employment, unemployment, investments , consumption, export etc.
  - Impact on welfare
  - Different financing scenarios considered (VAT, PIT, G, T)
- Kalman filter as a forecasting tool

Information for Kalman filter delivered by MIND module

- **Data on CAPEX, OPEX & efficiency gains in sectors**
- **Data on government subsidies**

BAU vs full abatement package



Impact of the full package (dev. from BAU)

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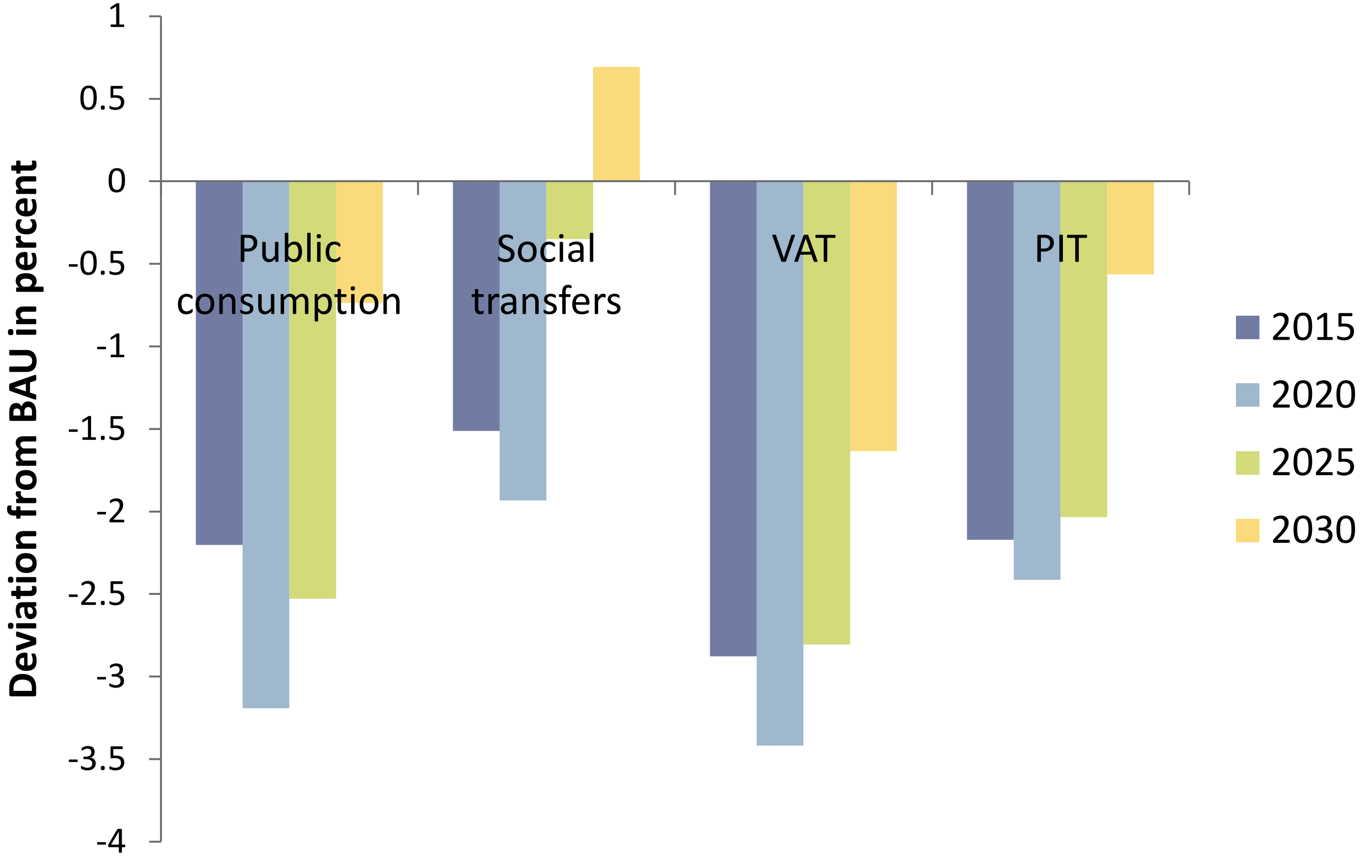
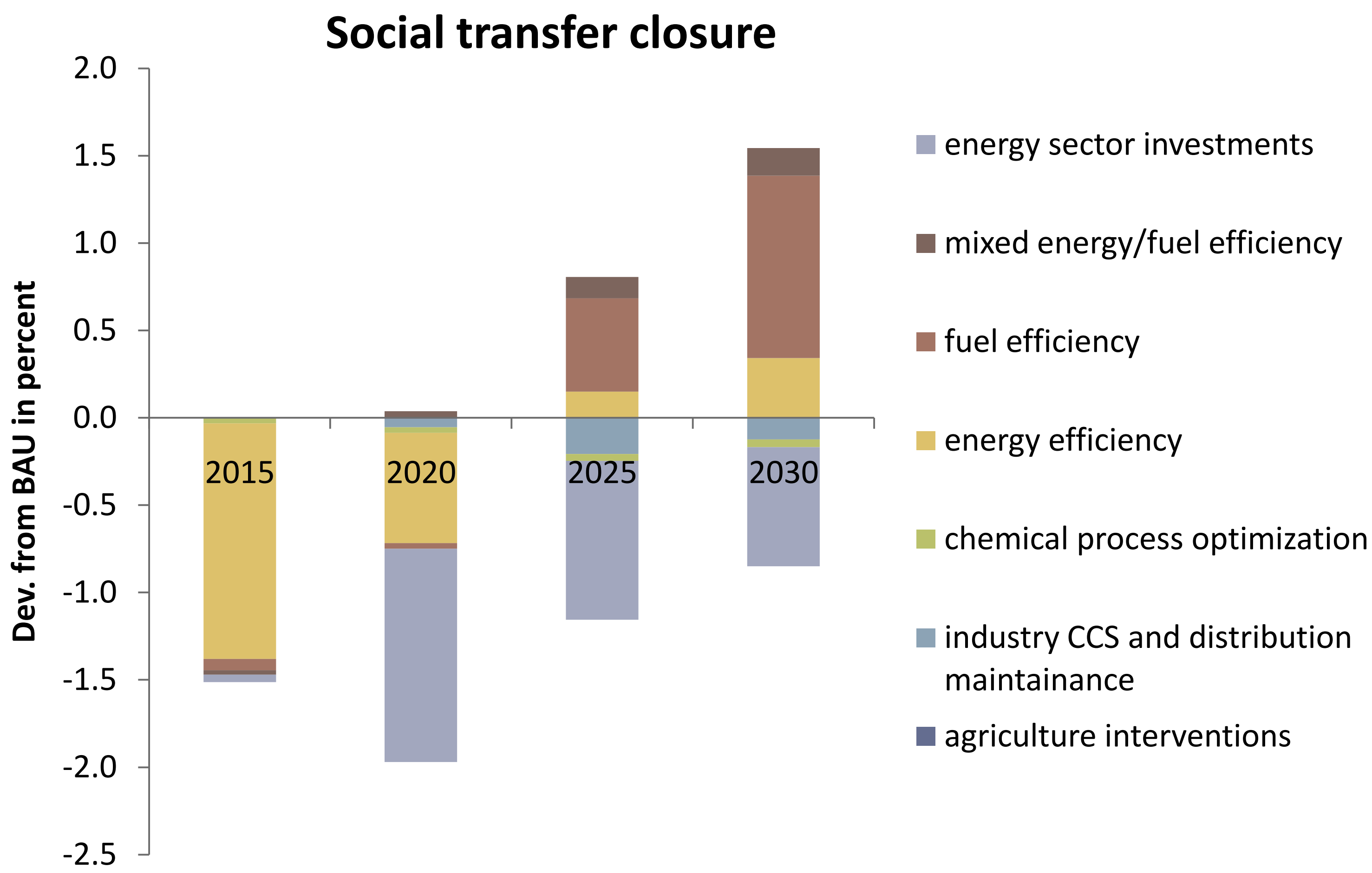
Closure	Variable	2015	2020	2025	2030
VAT	GHG emissions	-10.56	-24.14	-39.48	-47.50
	GDP	-1.53	-1.79	-0.83	0.16
	Value Added	-2.88	-3.42	-2.81	-1.63
	Employment	-2.59	-0.52	-0.20	-0.85
	Welfare	-1.85	-2.88	-1.54	-0.66
	Government expenditures	1.75	3.23	6.06	5.58
	Government revenues	2.19	2.59	4.30	4.77

Value added (dev. from BAU)



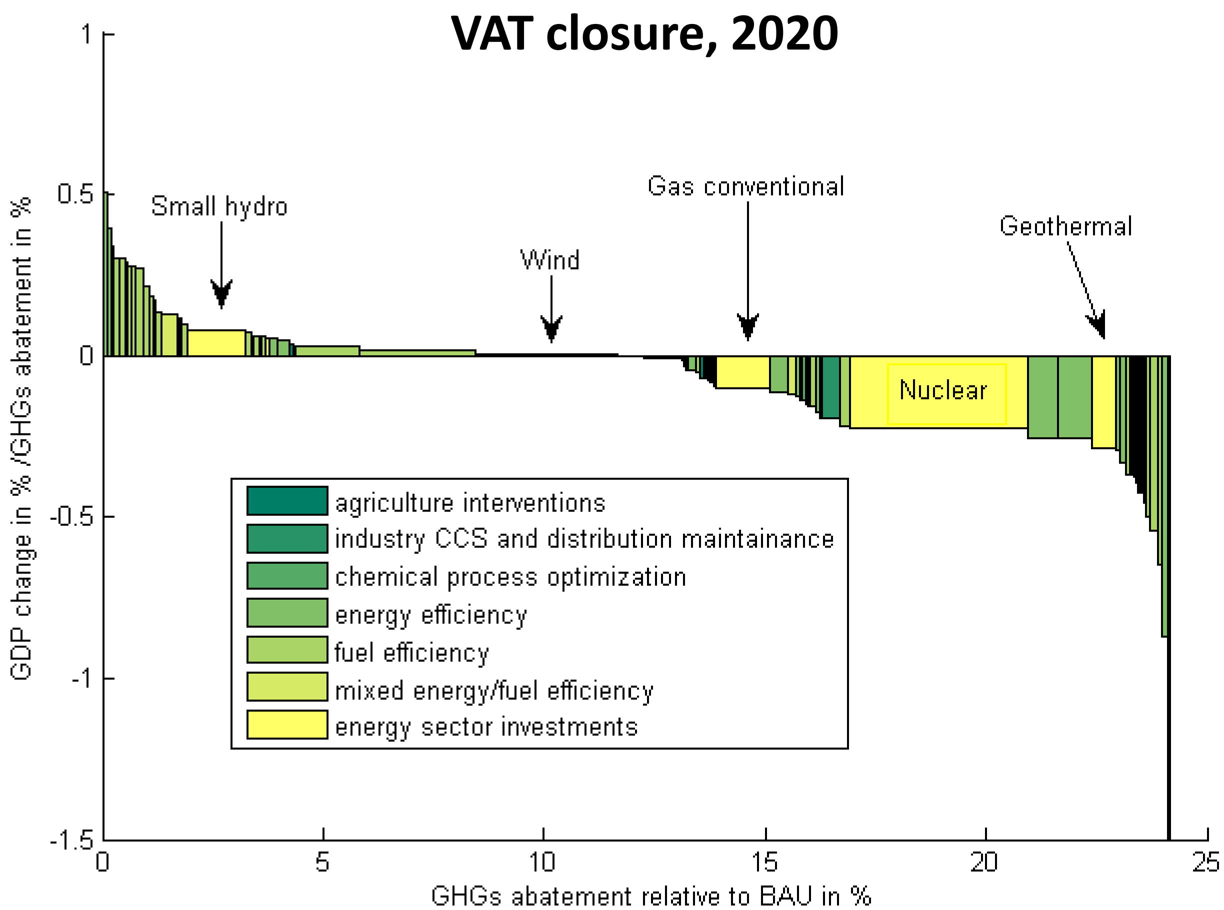
Value added (role of subpackages)



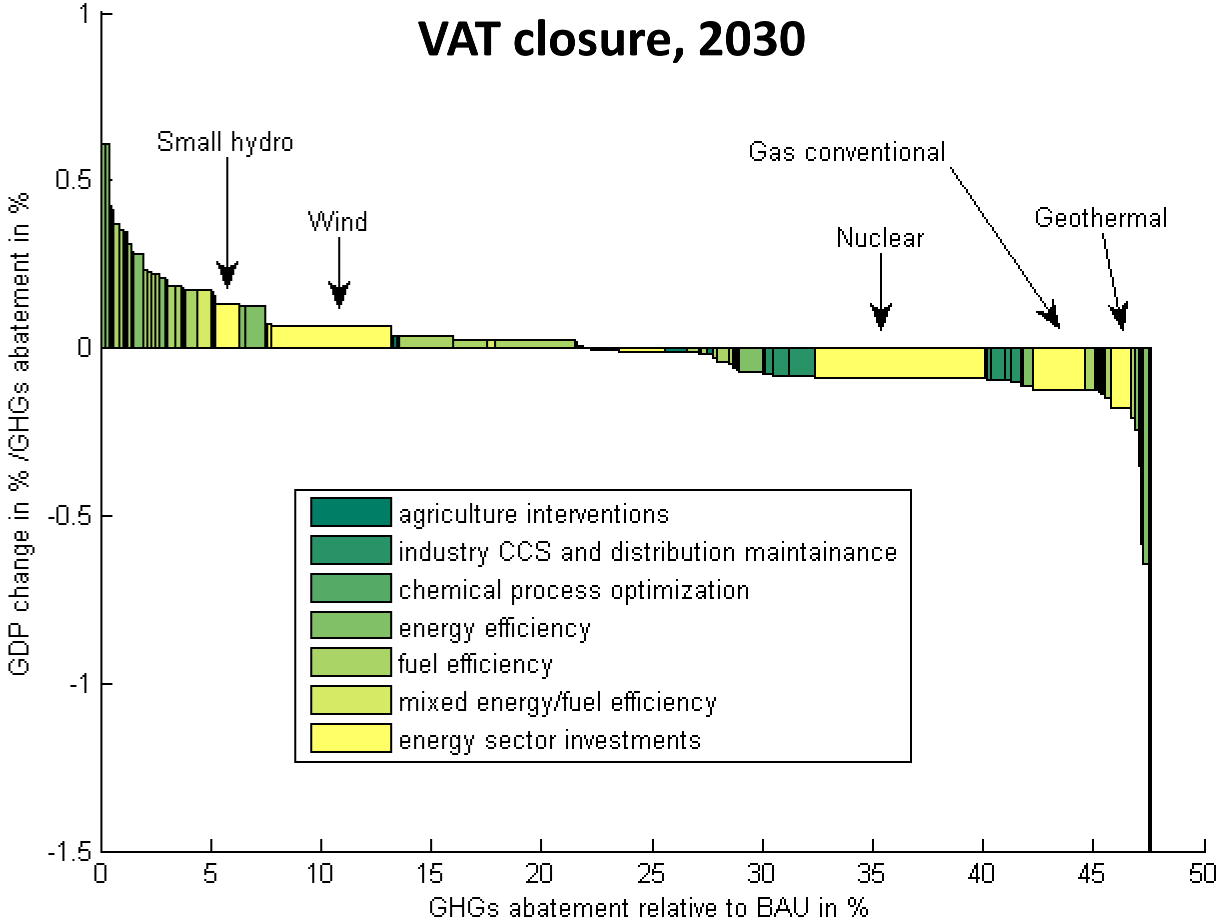
Impact of the package on ETS and Non ETS sector (dev. from BAU)

Closure	Variable	2015	2020	2025	2030
VAT	VA in ETS	-4.06	-5.76	-7.51	-9.06
	VA in Non-ETS	-2.72	-3.10	-2.16	-0.60
	Employment in ETS	-3.38	-1.19	-2.73	-5.15
	Employment in Non-ETS	-2.29	-0.52	0.17	0.39
	GHG emission in ETS	-11.60	-27.38	-44.20	-52.46
	GHG emission in Non-ETS	-11.14	-23.15	-38.05	-46.60
	GHG emission in households	-0.54	-3.22	-4.56	-4.00
	Emission intensity of VA	-7.91	-21.45	-37.73	-46.63
	Energy intensity of VA	-0.53	-7.86	-11.02	-11.57

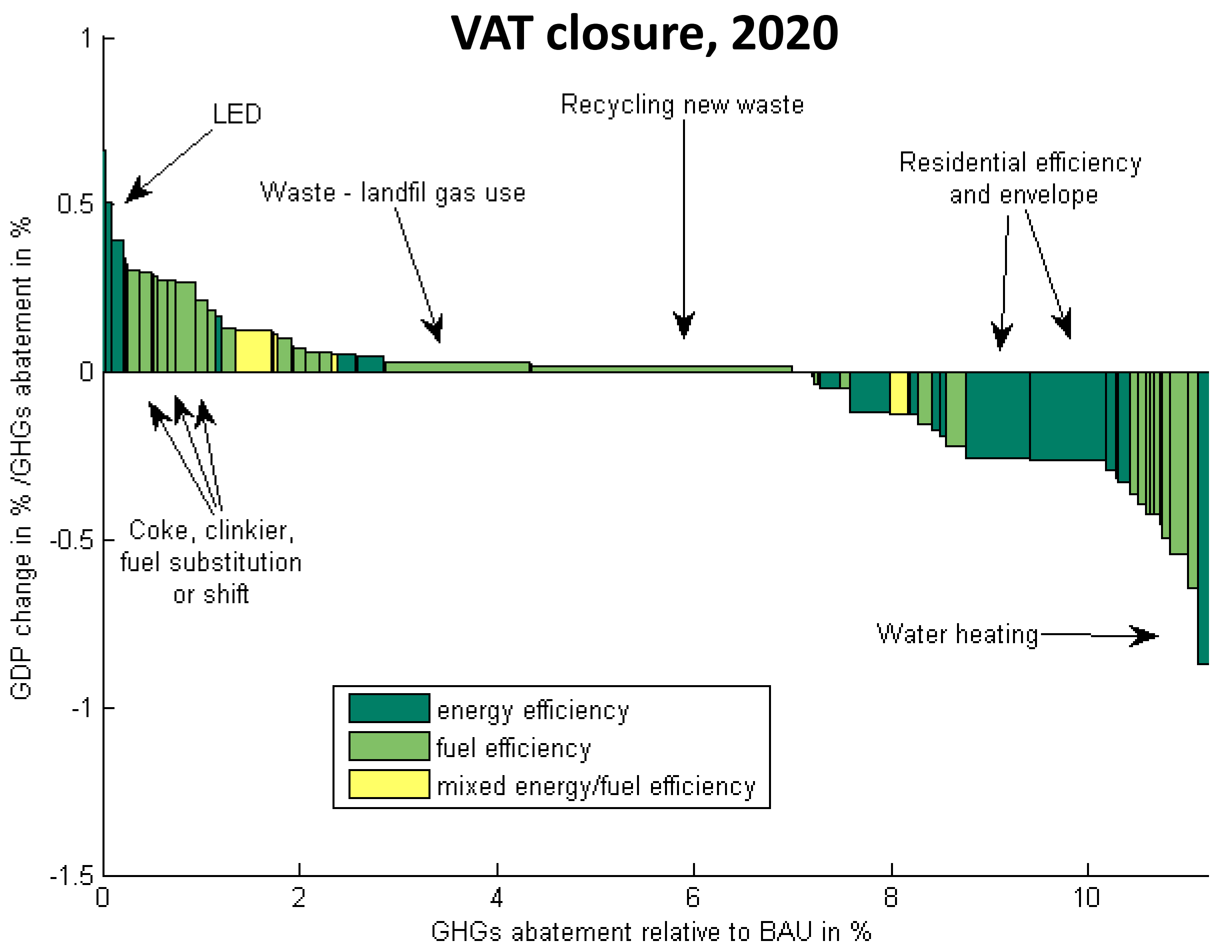
Full MAC-ρ curve (2020)



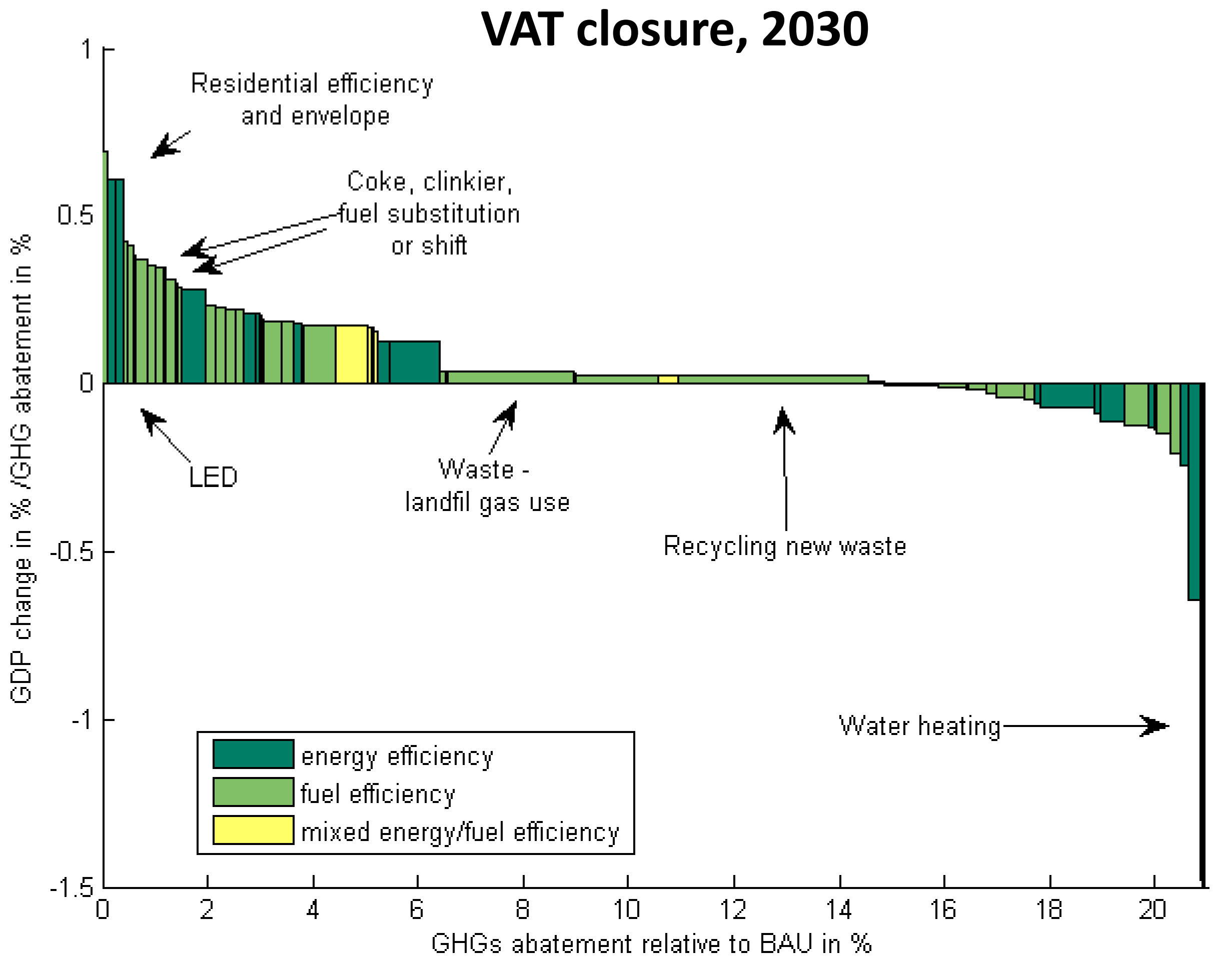
Full MAC-ρ curve (2030)



Energy eff. MAC-ρ curve (2020)



Energy eff. MAC-ρ curve (2030)



Basic conclusions

- **DSGE modeling framework** can **successfully be used** for climate and energy policy assessment. **Large scale, multisector DSGE** models combine advantages of both CGE and DSGE modeling approach;
- Macroeconomic impact of the GHG abatement packages strongly **depends** on its **composition**, **financing** and **time horizon** in which it is considered;
- Energy and/or fuel **efficiency gains are the most promising** with respect to the positive impact on the economy;
- **Negative macroeconomic influence of investments in non-emitting power generation lasts longer** due to necessary large CAPEX expenditures that must be spent up-front;
- **ETS** and **Non-ETS** sectors **are affected differently** even if **no direct carbon taxation** is implemented.

Thank you for your attention

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