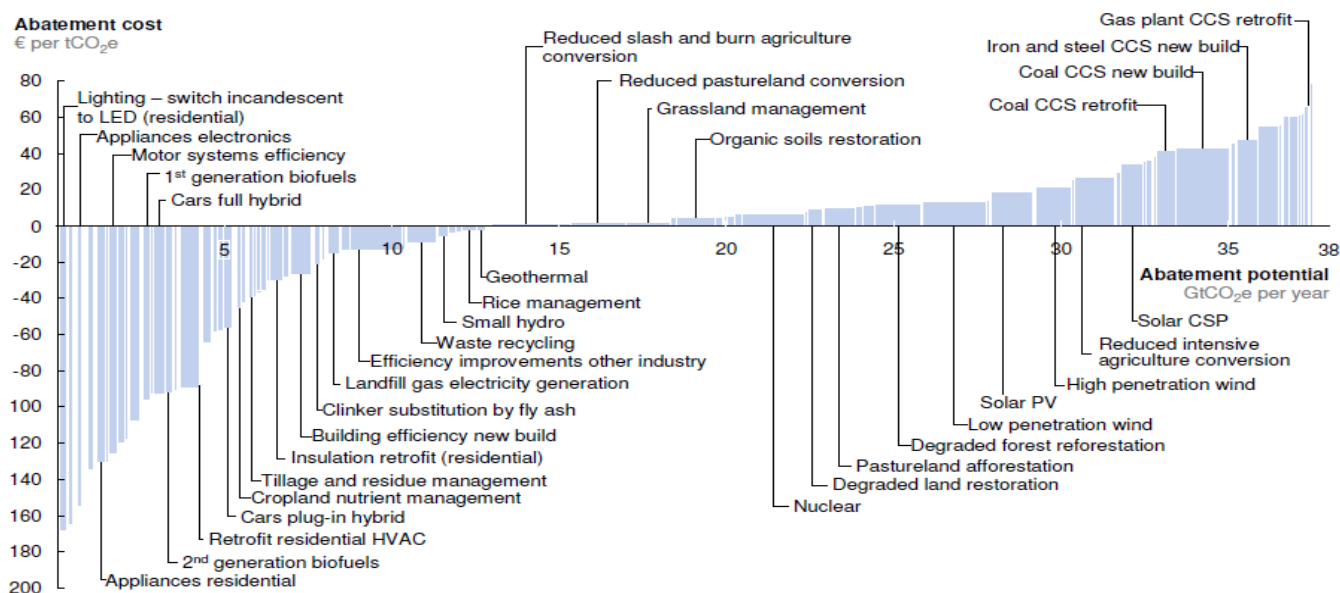


MARGINAL ABATEMENT COST CURVES AND TECHNO-ECONOMIC CARBON PRICE MODELS FOR ETS

Dr. Vicki Duscha, Fraunhofer ISI

International Modelling Conference, 12 October 2016, Seoul



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

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Agenda

- Modelling for ETS
- Marginal abatement cost curves
 - Characteristics
 - Examples
 - Shortcomings
- Techno-economic models
 - Characteristics
 - Examples
- Development of MACCs from techno-economic models
- Wrap up

Modelling for ETS

- Why do we want to model?
- Different questions
- Different model types

Modelling for ETS

Why do we want to model?

- Policy
 - Design of policy instruments
 - Evaluation of different measures/ proposals
- Firms under the ETS
 - Develop a mitigation strategy
 - Develop trading strategy
- Industry associations
 - Lobbying purposes
- Financial institutions/ financial service providers
 - Develop trading strategies for themselves and for their clients

Modelling for ETS

Different questions I

- General climate policy–related questions
 - What are the abatement potentials in different sectors?
 - What are the abatement costs in different sectors?
 - What are cost–effective solutions
 - Within the EU ETS
 - In the economy overall (burden–sharing between ETS and non–ETS sectors)
 - What happens if the scope of the ETS changes?
 - What kind of interactions exist between the ETS and other policy instruments (ex–ante) and how do they affect the ETS and the other policy instruments?
 - What are the contributions of the ETS to meeting the Energiewende targets/ GHG targets in general?

Modelling for ETS

Different questions II

- Design elements of the (EU) ETS
 - How does the allocation methodology affect installations under the EU ETS (free allocation, grandfathering, benchmarking, auctioning of permits)?
 - What do stability mechanisms do (price collars, minimum prices, maximum prices, market stability reserve)?
 - How does linking affect the ETS systems?
 - What competitiveness effects can be expected from the introduction/ certain levels of ambition within an ETS?
 - Do we expect carbon leakage? To what extent? Can measures help to prevent carbon leakage (border carbon adjustments, free allocation of permits)?
 - What cost-burden occurs from the ETS?
 - What CO₂ prices do we expect?
 - In the short-term
 - In the long-term

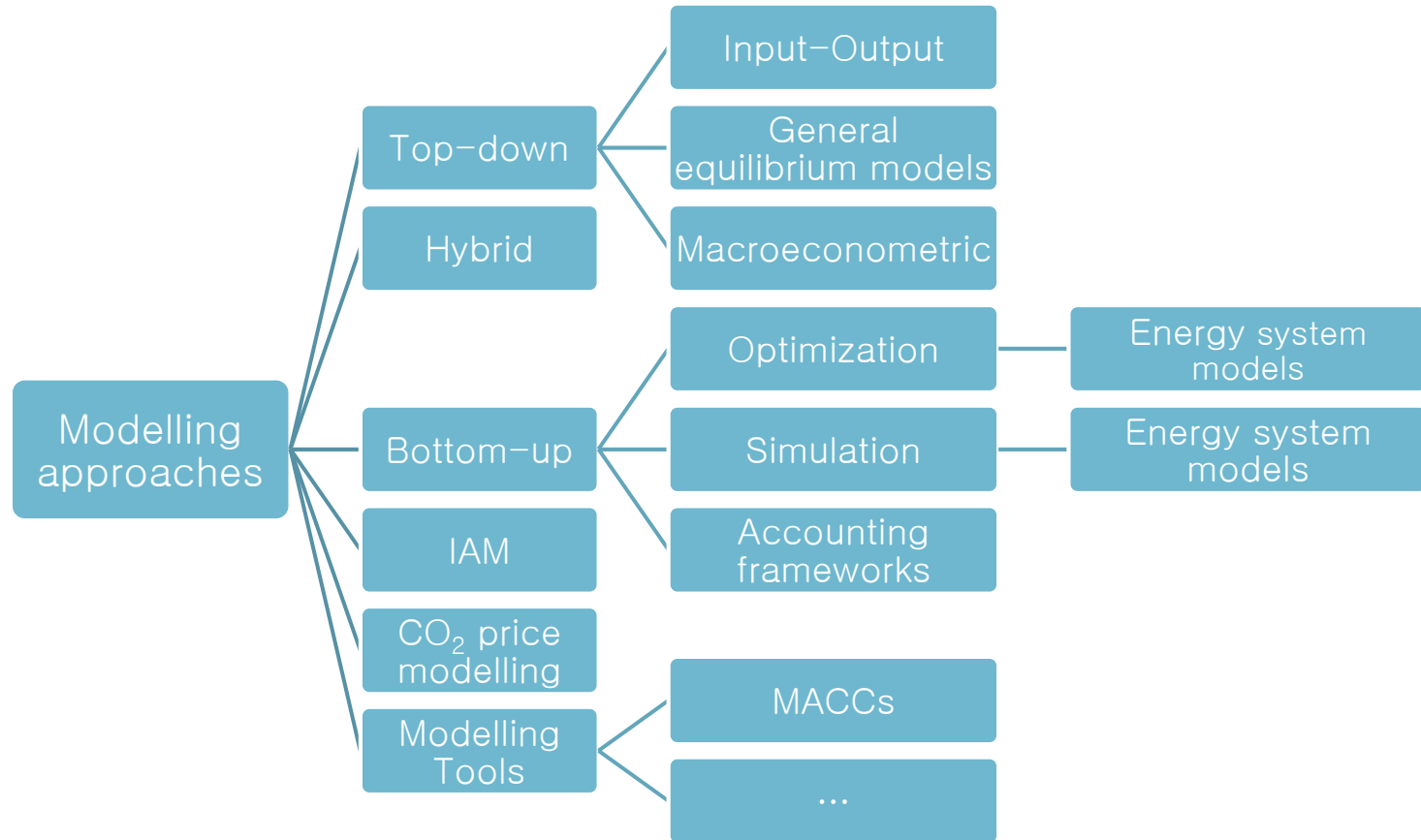
Modelling for ETS

Different questions III

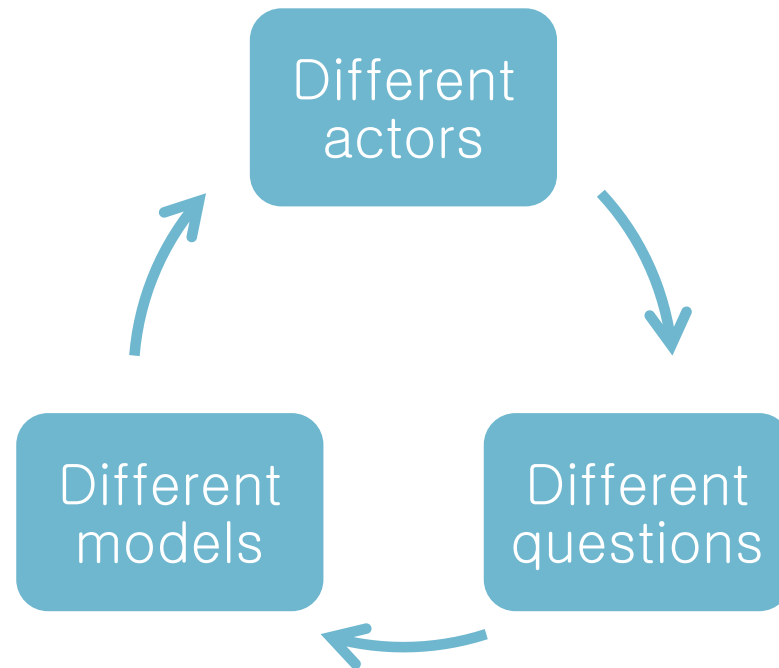
- Evaluation of the ETS
 - How effective was the system?
 - How cost-efficient was the system?
 - What were the interactions with other policy instruments?

Modelling for ETS

Different models



Modelling for ETS



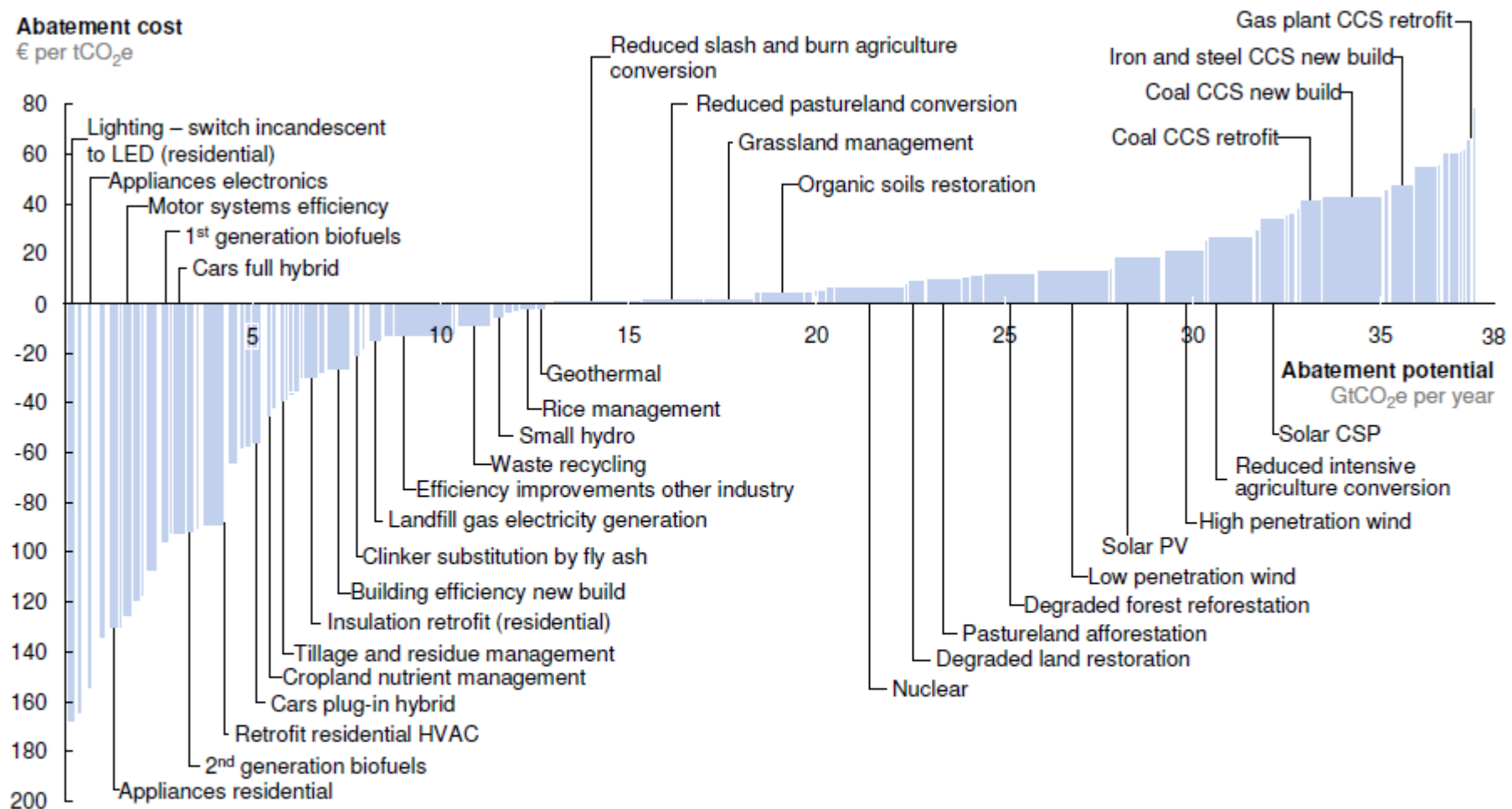
In the following, we look at

- MACCs
- Techno-economic modelling

Marginal abatement cost curves

- An example & history
- Characteristics
- Shortcomings

Global marginal abatement cost curve (MACC or MAC curves) by Mc Kinsey



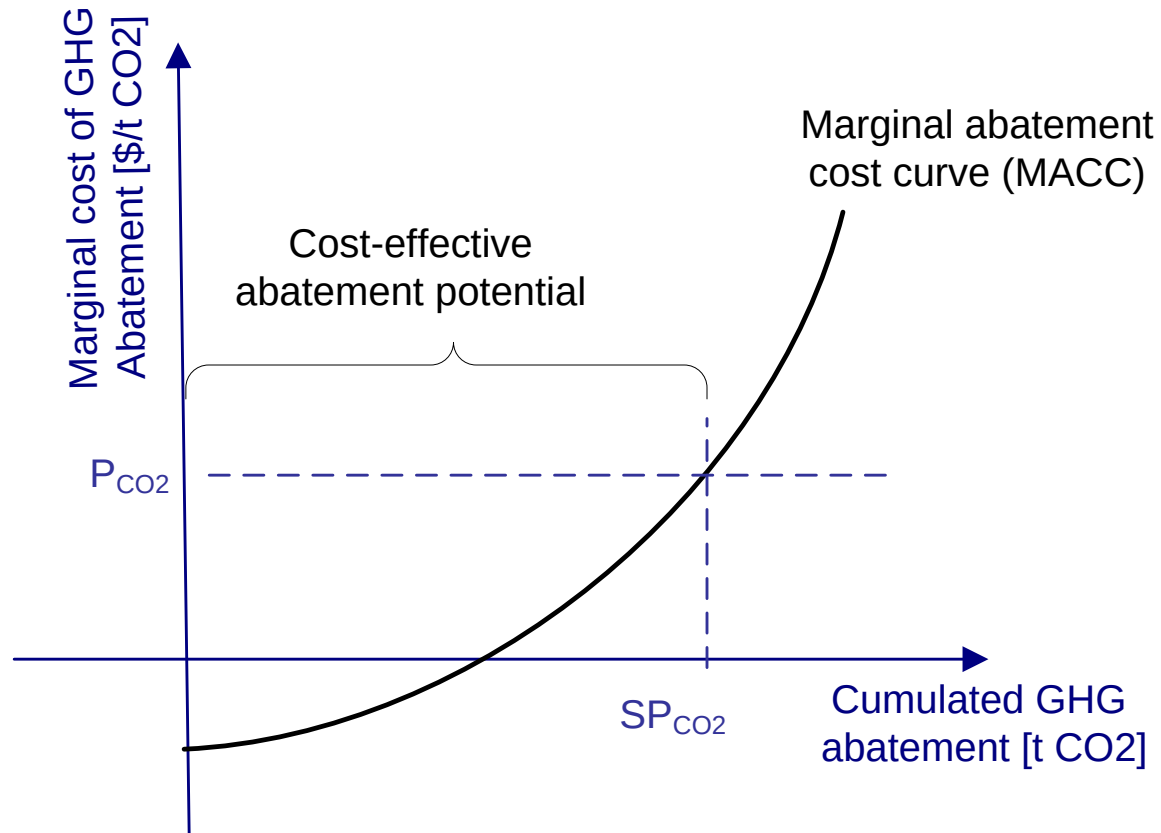
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Source: Global GHG Abatement Cost Curve v2.1

A brief history of MACC development

- **The 1980s:** First curves emerge for energy savings
 - Meier and Rosenfeld develop conservation supply curve for electricity savings (see e.g. Meier 1982)
 - First steps to raise awareness that energy savings can also be regarded as supply of energy → “name conservation supply curves”
- **1990s:** MAC curves extension to greenhouse gases
 - Many applications for energy/electricity savings for many sectors and countries
 - Use also for new fields among which greenhouse gas mitigation (see e.g. Lovins and Lovins 1991, Blok et al. 1993)
- **Beyond 2000:** MAC curves popularized by McKinsey and
 - McKinsey global MAC curves gain much attention
 - Also critics of MAC curve concept emerge directing at simplification

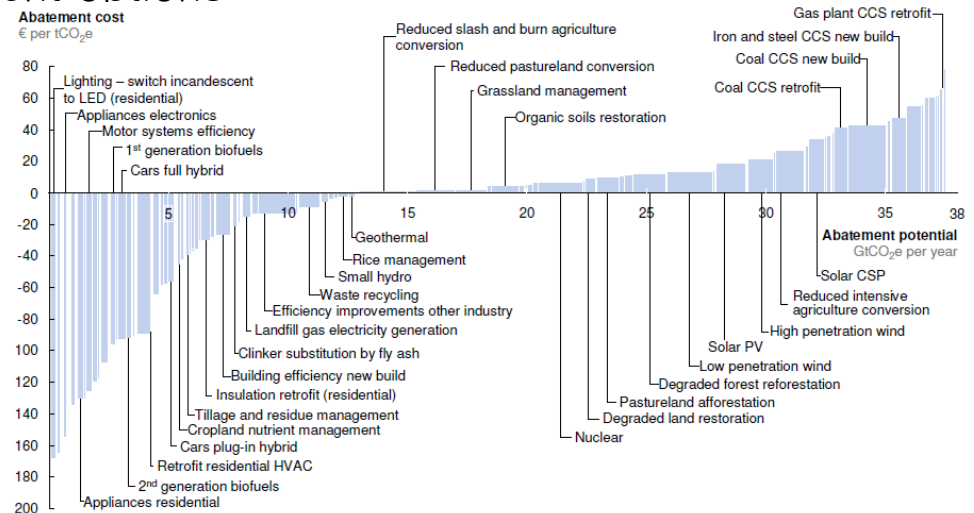
Conceptual description of a MACC



Source: Fleiter et al. 2009

Basis for MACCs of the McKinsey type

- Bottom-up calculation of individual abatement options (maybe model based, but can also be very simple by systematically collecting information on abatement options)
 - Very illustrative way of showing the contribution of individual technologies/ abatement options



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

Bottom-up calculation by analysis of individual measures: Specific costs

The idea:

$$\text{SpecificAbatementCost} = \frac{\text{DifferenceInCosts}}{\text{DifferenceInEmissions}}$$

Calculation of specific abatement cost per year using simple investment framework:

Initial Investment cost of one unit

Difference in annual running cost of one unit

Annual energy cost savings (Difference in energy cost spendings of one unit)

$$AC_{CO_2}^{sp} = \frac{AF * IC + RC - SaveEC}{SaveCO_2}$$

Annual CO2 savings of one unit

The formula is simple. But: the trick is to calculate/define these input values!

Marginal abatement cost curves

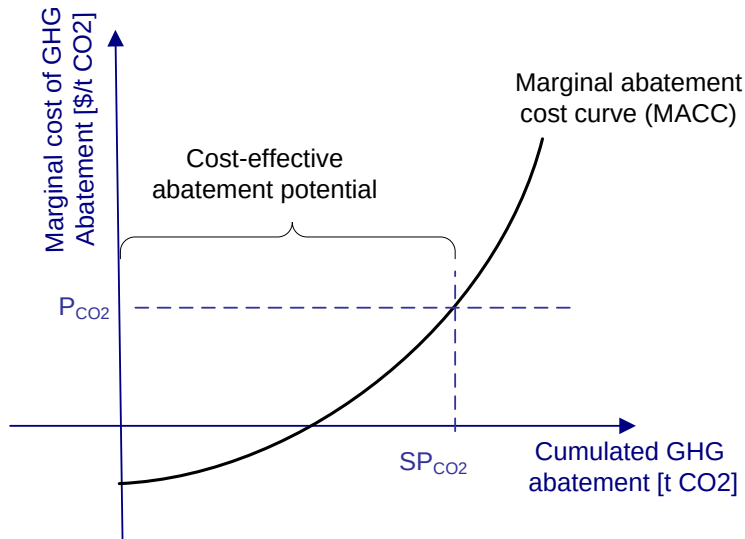
Characteristics

$$AC_{CO_2}^{sp} = \frac{AF * IC + RC - SaveEC}{SaveCO_2}$$

- **Abatement costs:** specific abatement costs
- **Cost perspective:** social vs. private costs
 - What interest rates should be used?
 - What is the depreciation period for your technology?
 - Are taxes and subsidies included?
- **System boundaries:**
 - Time frame
 - Geography
 - Technologies
 - Sectors/ economy

Marginal abatement cost curves

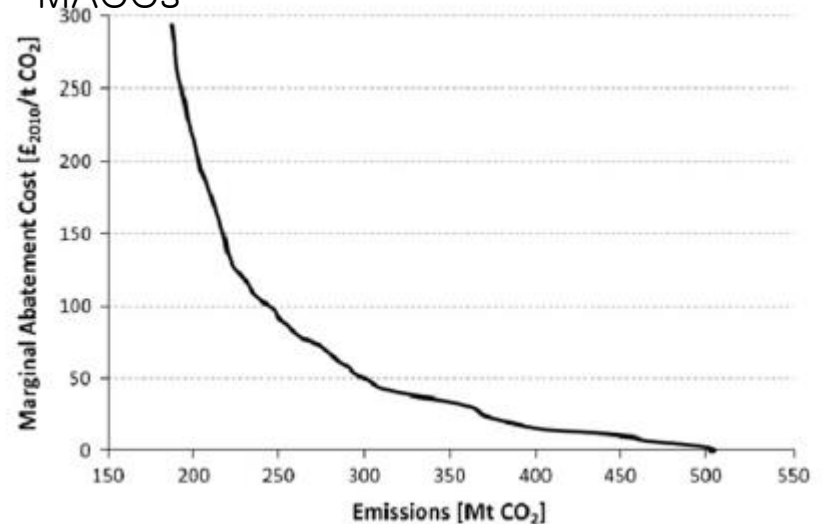
Definition of the reference



Source: Fleiter, 2009

One option for presenting MACCs

Alternative option for presenting MACCs

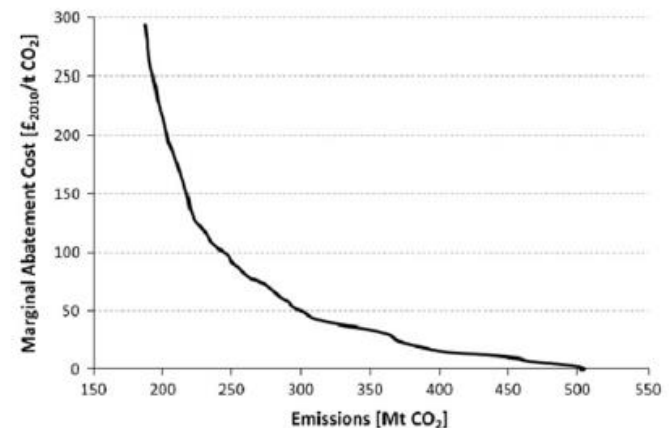


Source: Kesicki, 2013

Marginal abatement cost curves

Reference and framework parameters

- Definition of a reference/ reference point:
 - Defines to a large extent the abatement potential available
 - Can include the definition of alternative technologies that would be applied otherwise
 - Can affect abatement costs if cost differences are looked at
- Framework parameters:
 - Definition of energy prices/ energy price dev
 - Definition of production levels



Source: Kesicki, 2013

Determinants of the final curve

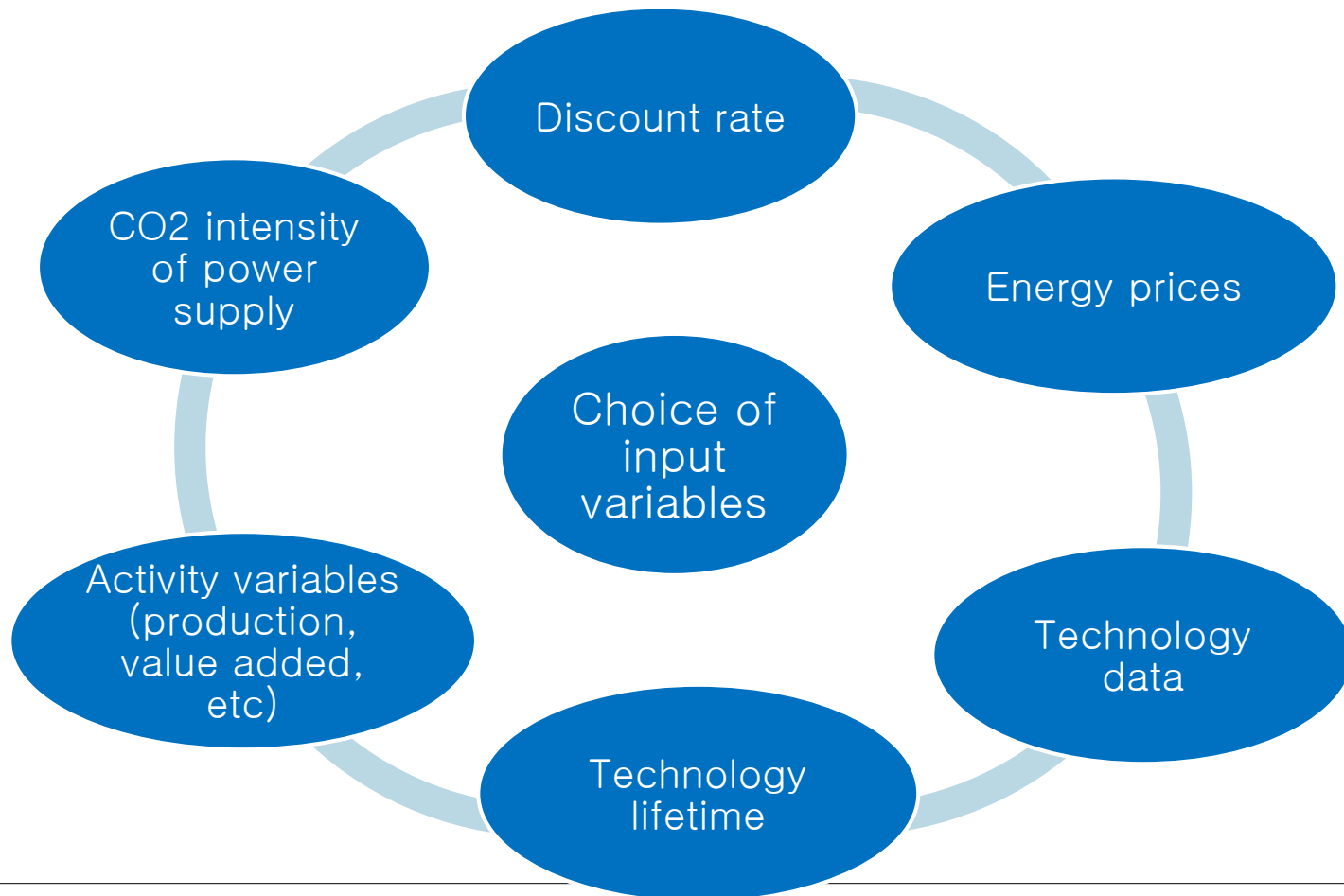
*What is influencing the shape of the MAC curve?
→ Three types of factors can be distinguished:*

Input variables
and data

Methodological
decisions

Methodological
shortcomings/
deficits

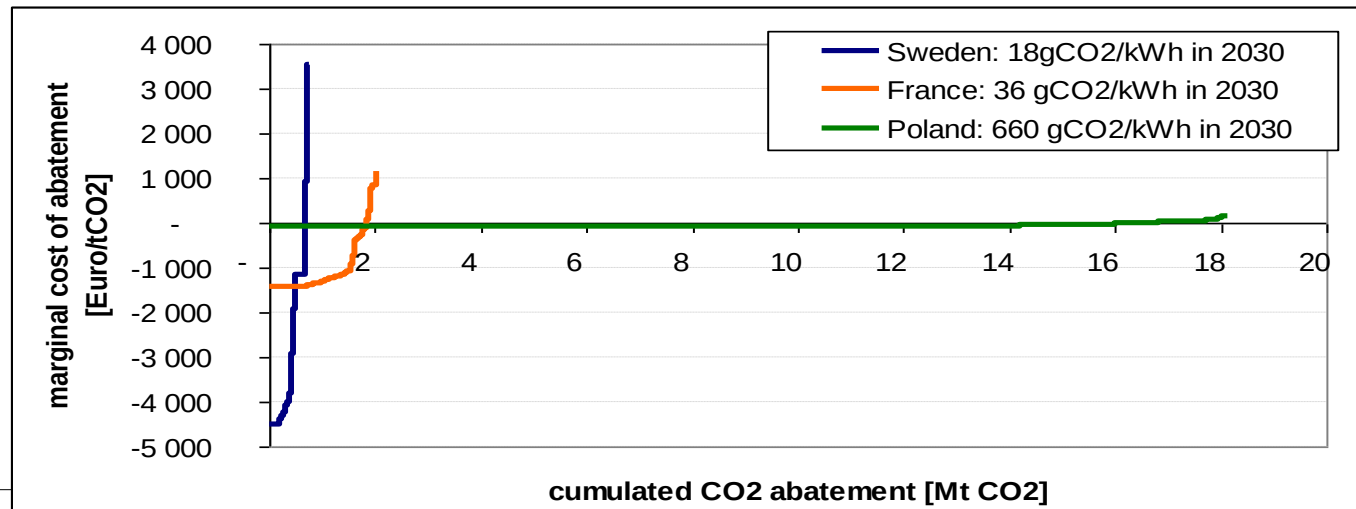
Choice of input variables



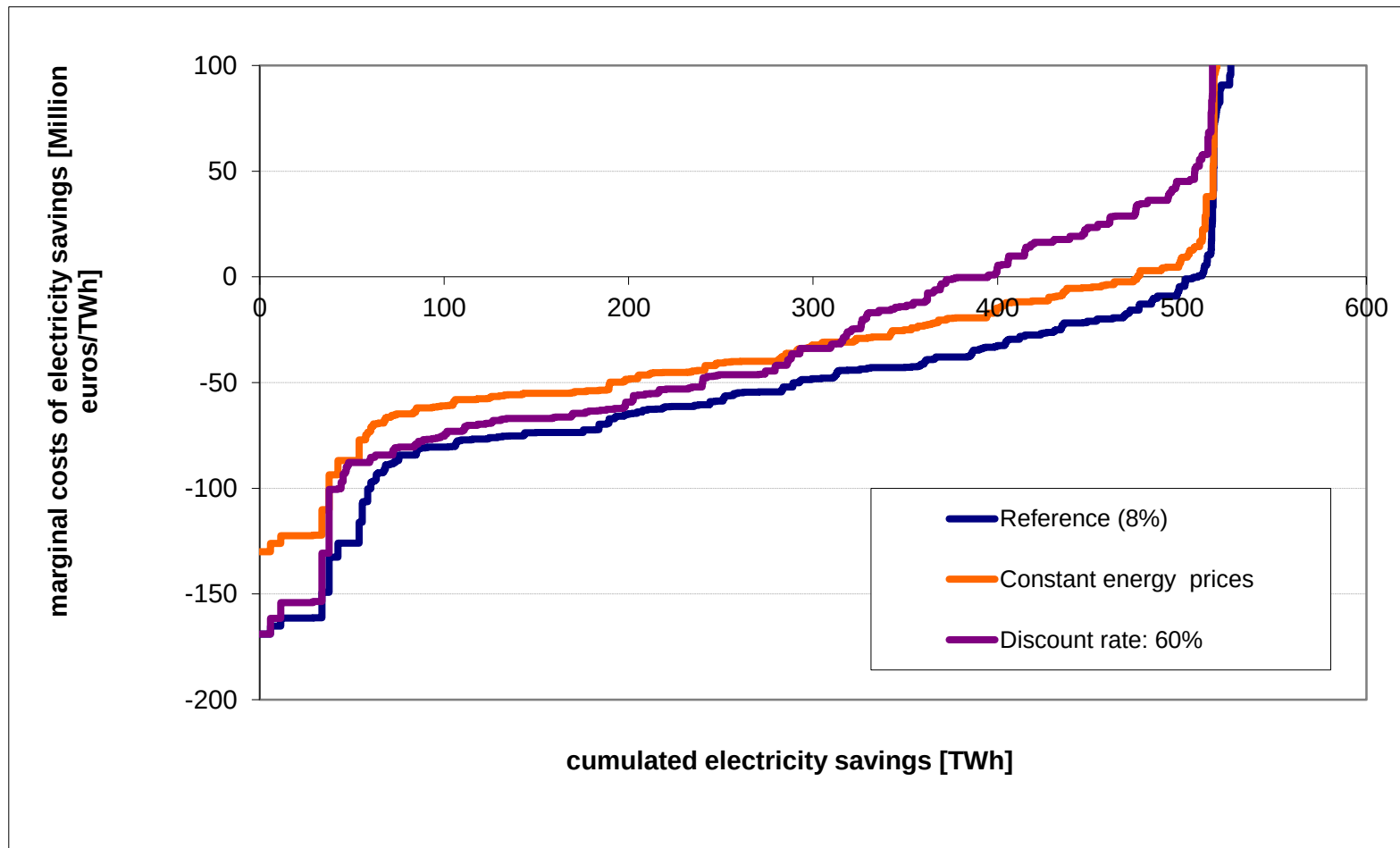
Choice of input variables II

■ CO₂ intensity of power supply:

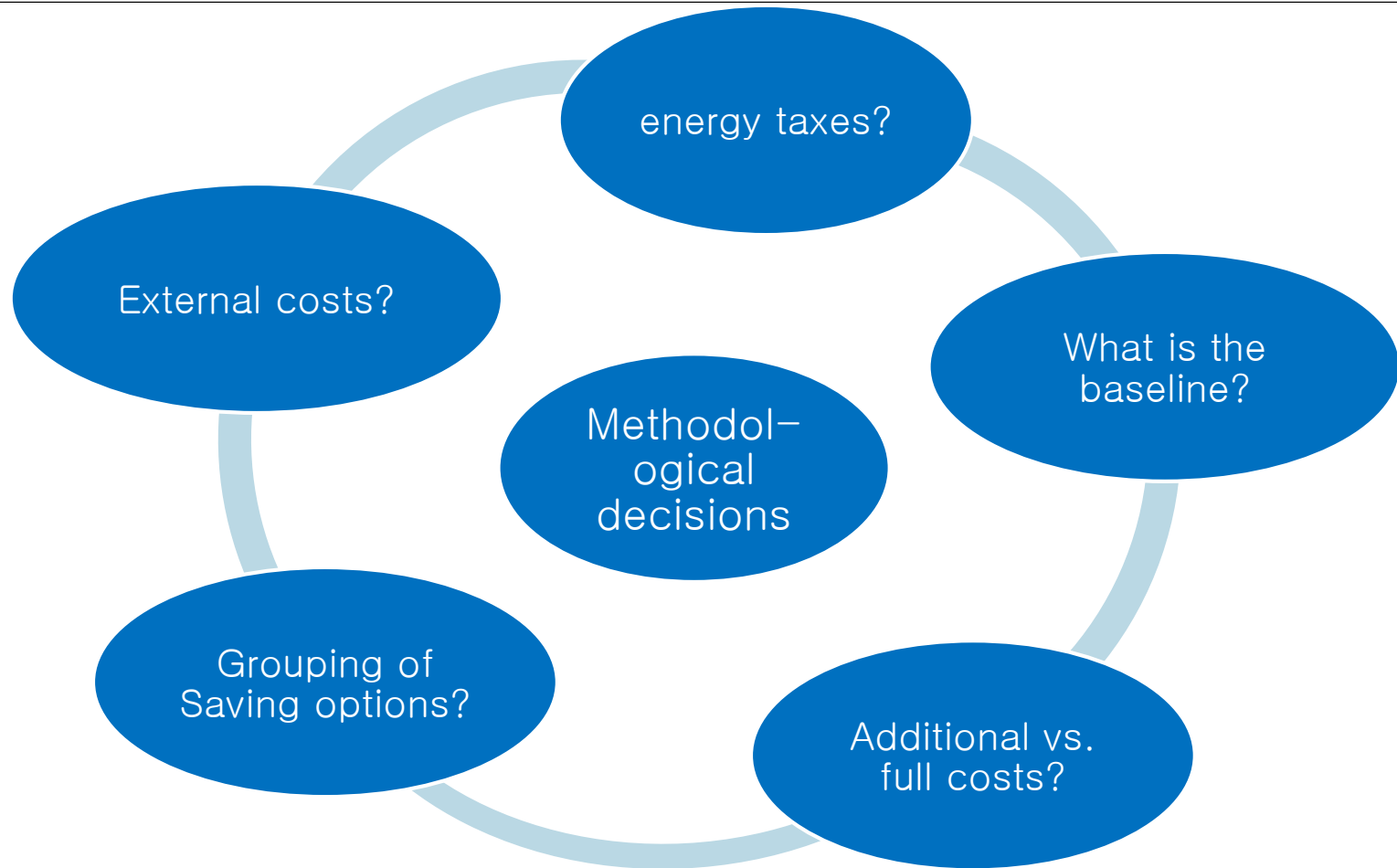
	Country 1	Country 2
Electricity savings due to use of efficient motor	1 MWh/a	1 MWh/a
Financial savings due to conserved electricity	50 €/a	50 €/a
CO ₂ intensity of power generation	600 g CO ₂ /kWh	20 g CO ₂ /kWh
CO ₂ abatement related to the efficient motor	600 kg/a	20 kg/a
Costs of CO ₂ abatement	-50 € / 0.6 t = -83 €/t	-50 € / 0.02 t = -2500 €/t



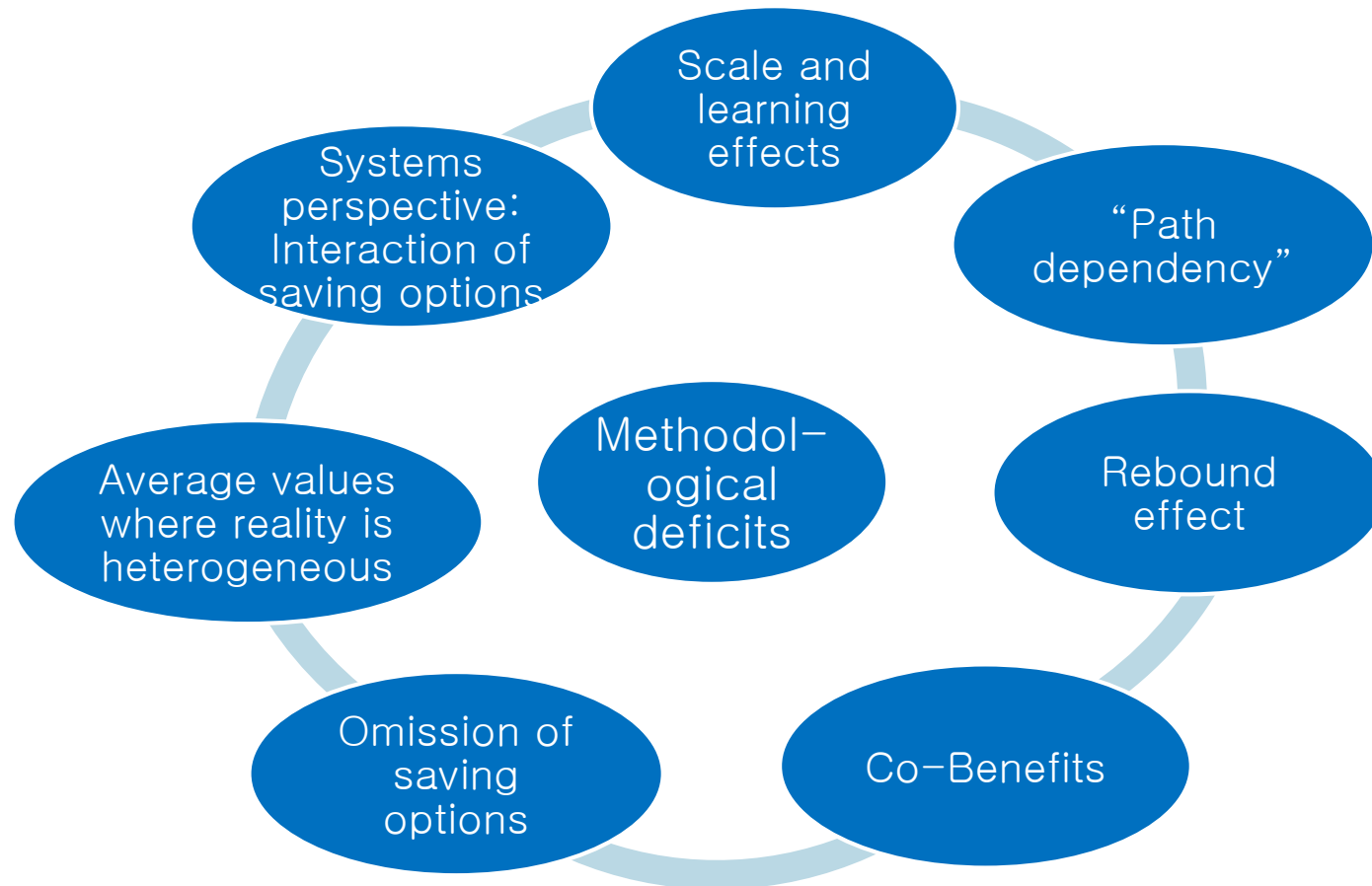
The effect of discount rate and price changes



Methodological decisions

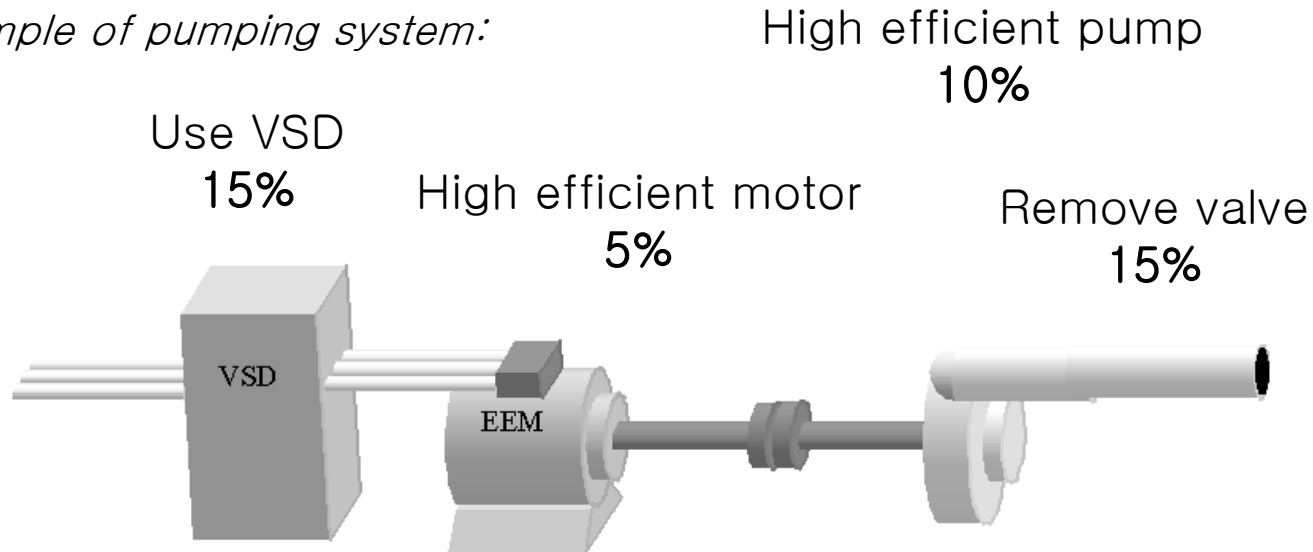


Methodological shortcomings



Interaction of saving options

- *Example of pumping system:*

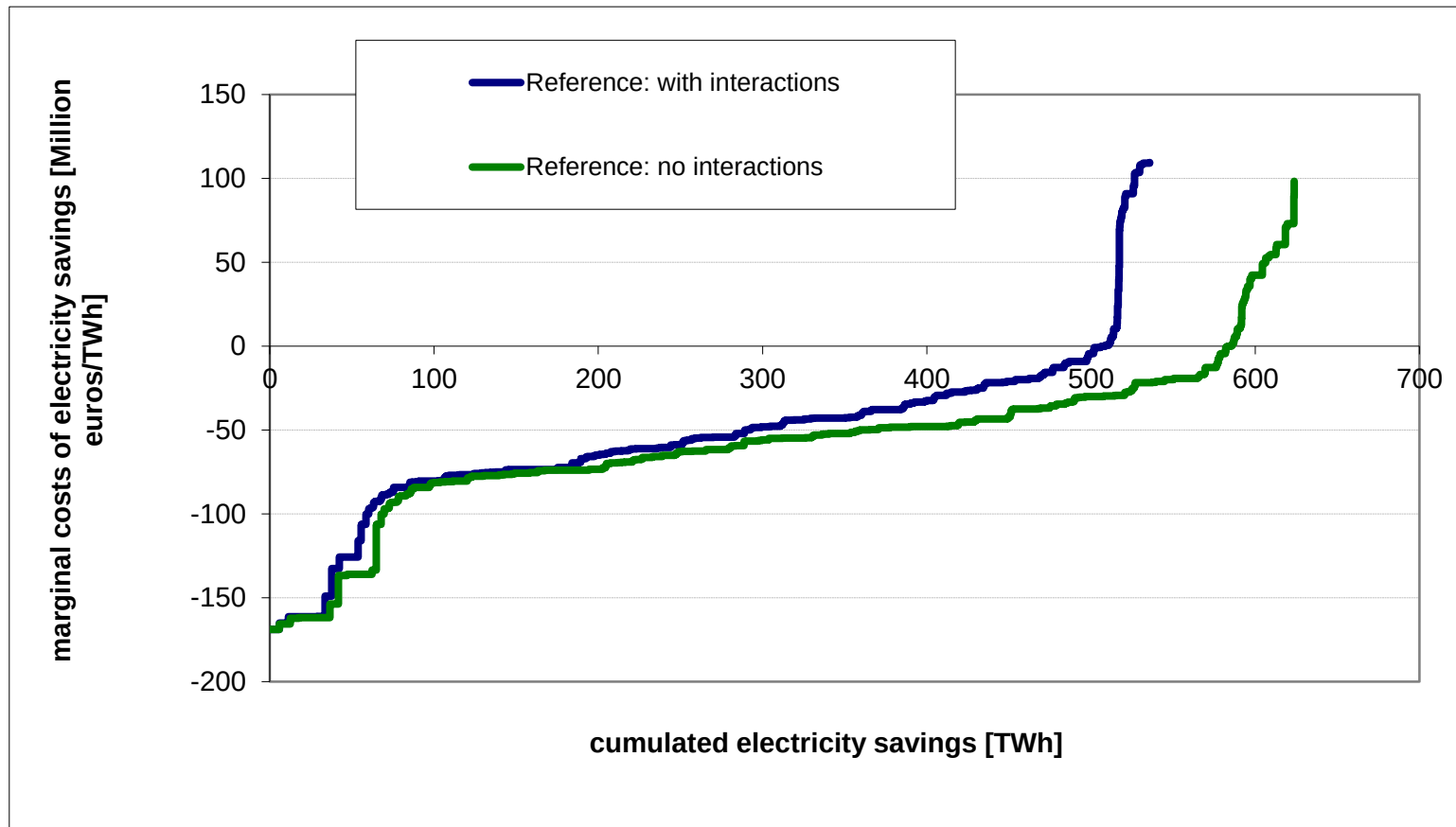


Sum of distinct saving options: **45%**

→ Total saving potential for all system improvements: **38%**

→ How to allocate the 38% to the distinct saving options?!?

Interaction of saving options II

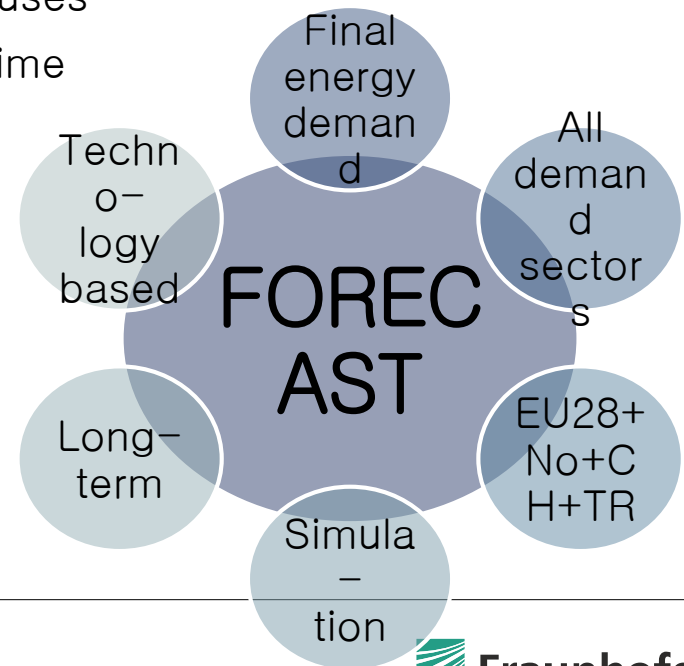


Techno-economic modelling

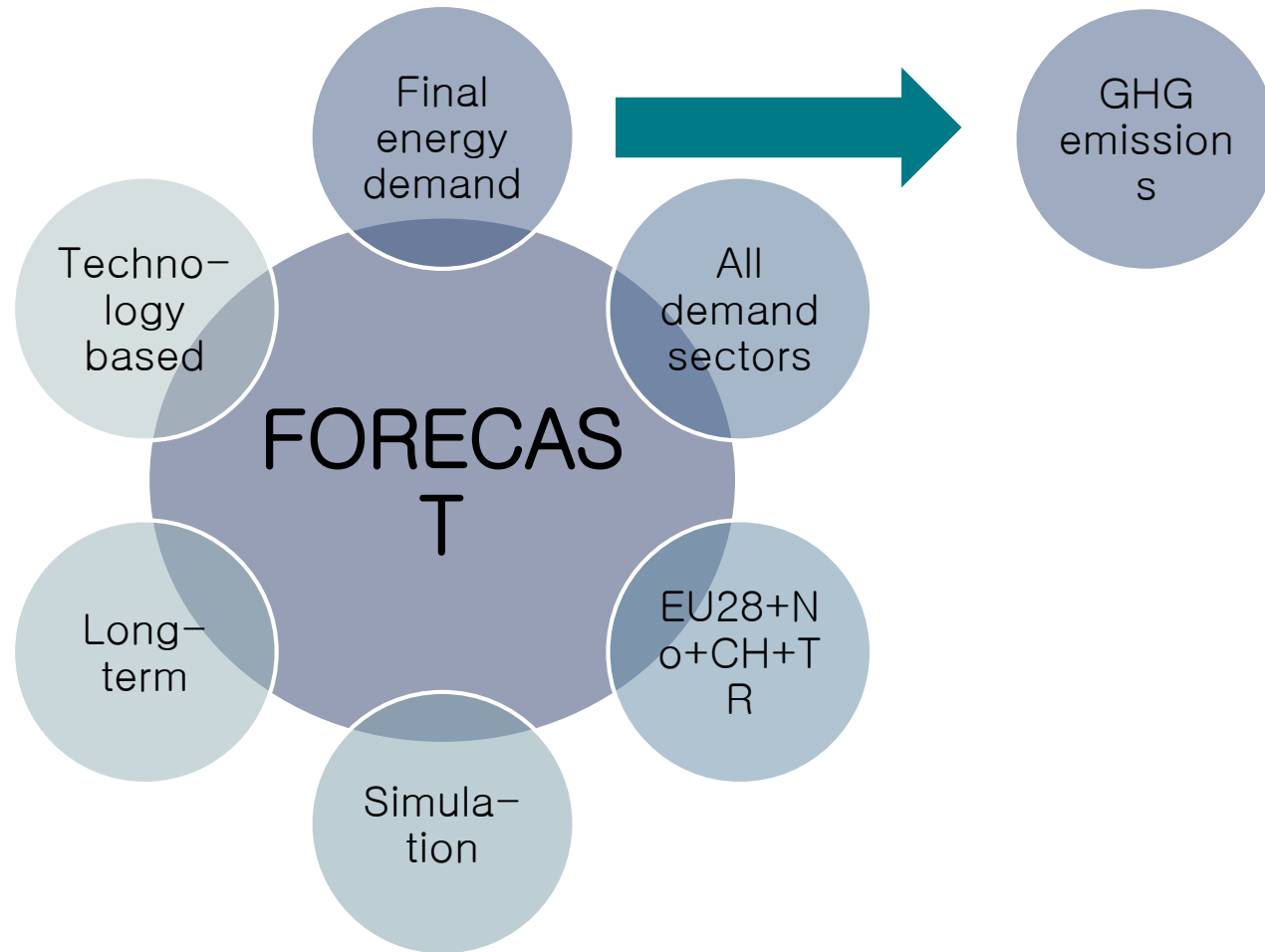
- Techno-economic modelling for ETS-related questions
- Example I: Energy demand modelling with Forecast & Forecast Industry
- Example II: Energy system/ power sector optimization with enertile

Techno-economic modelling for ETS-related questions

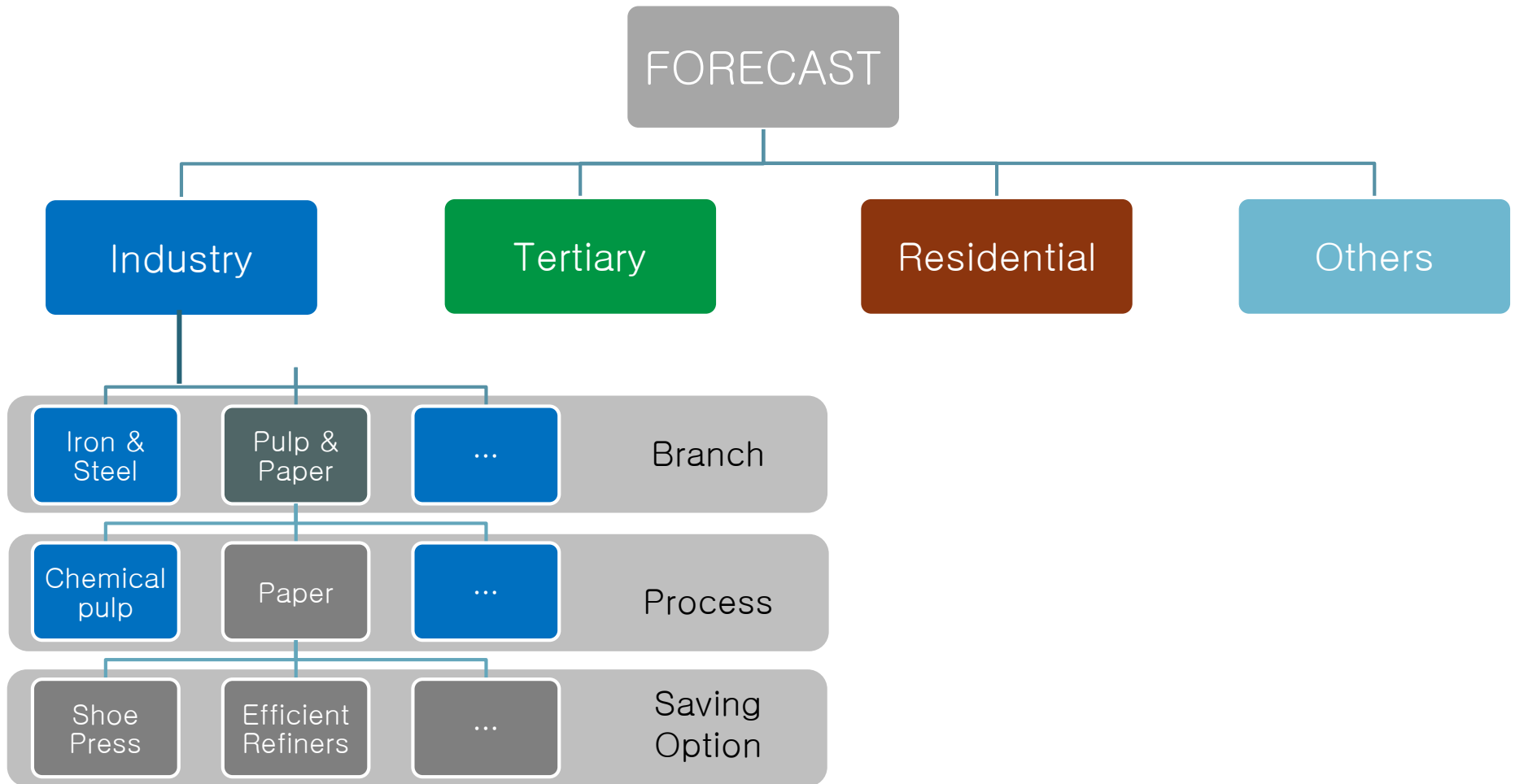
- While MACCs provide a good illustration of abatement potentials, many questions can better be answered by applying models
 - Techno-economic models provide a very systematic way of using technological abatement information as provided in McKinsey type MACCs
 - Definition of alternative scenarios and comparison of scenarios allows answering many questions with specific focuses
 - Handling of models is complex and needs time



Example I: Energy demand modelling with Forecast & Forecast Industry



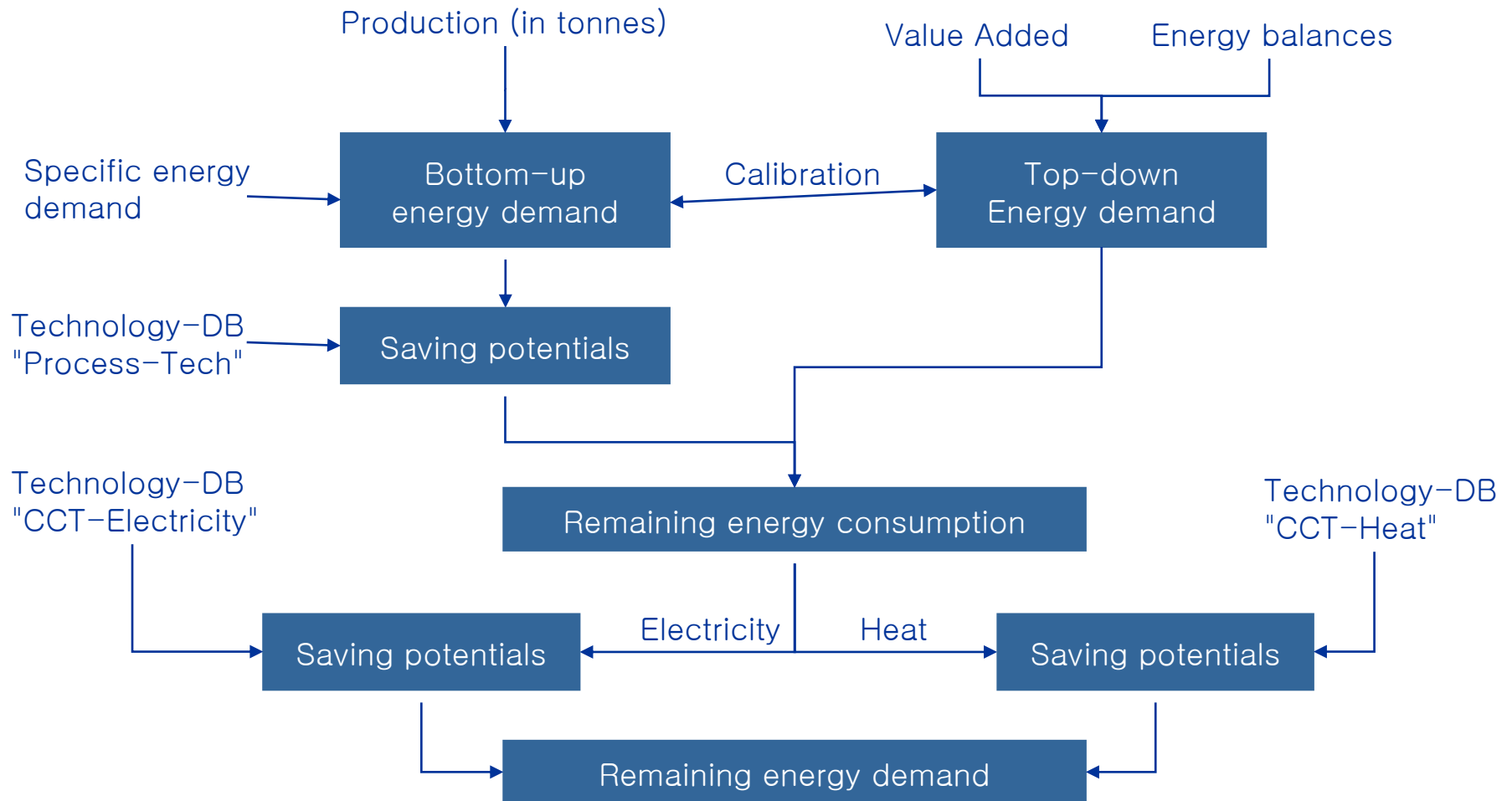
Example 1: Energy demand modelling with Forecast & Forecast Industry



Forecast: Main input parameters

	Tertiary	Households	Industry	Agriculture/ Transport
Main drivers	- Floor area per employee - No. of employees	- No of households - Building surface	- Physical production - Value added	- Production output - Irrigated areas - Passenger/Ton – km
Prices	- Energy prices	- Energy prices	- Energy prices - EUA Prices	
Technology data	Energy Services: - Technology driver - Installed power - Annual full load hours Saving options: - Saving Potential - Costs - Lifetime - Diffusion	Appliance data by efficiency class - Market share - Specific energy cons. - Lifetime - Standby power - Standby hours Building related data: - Insulation levels - Heating system efficiency - Heating and lighting technology shares	Processes: - Specific Energy Cons. Saving Options: - Saving Potential - Costs - Lifetime - Diffusion	Processes/Services - Technology driver - Specific energy demand -- Saving potential

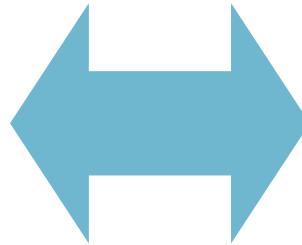
Simplified structure of the industry model



Technology classification

Process technologies

- Energy intensive
- Plant and process specific
- Iron furnaces, electrolysis plants, paper machine, glass furnaces, chemical reactors...

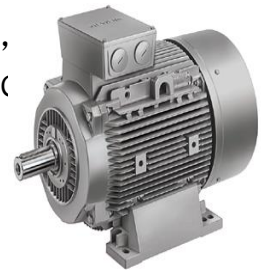


Cross-cutting technologies (CCT)

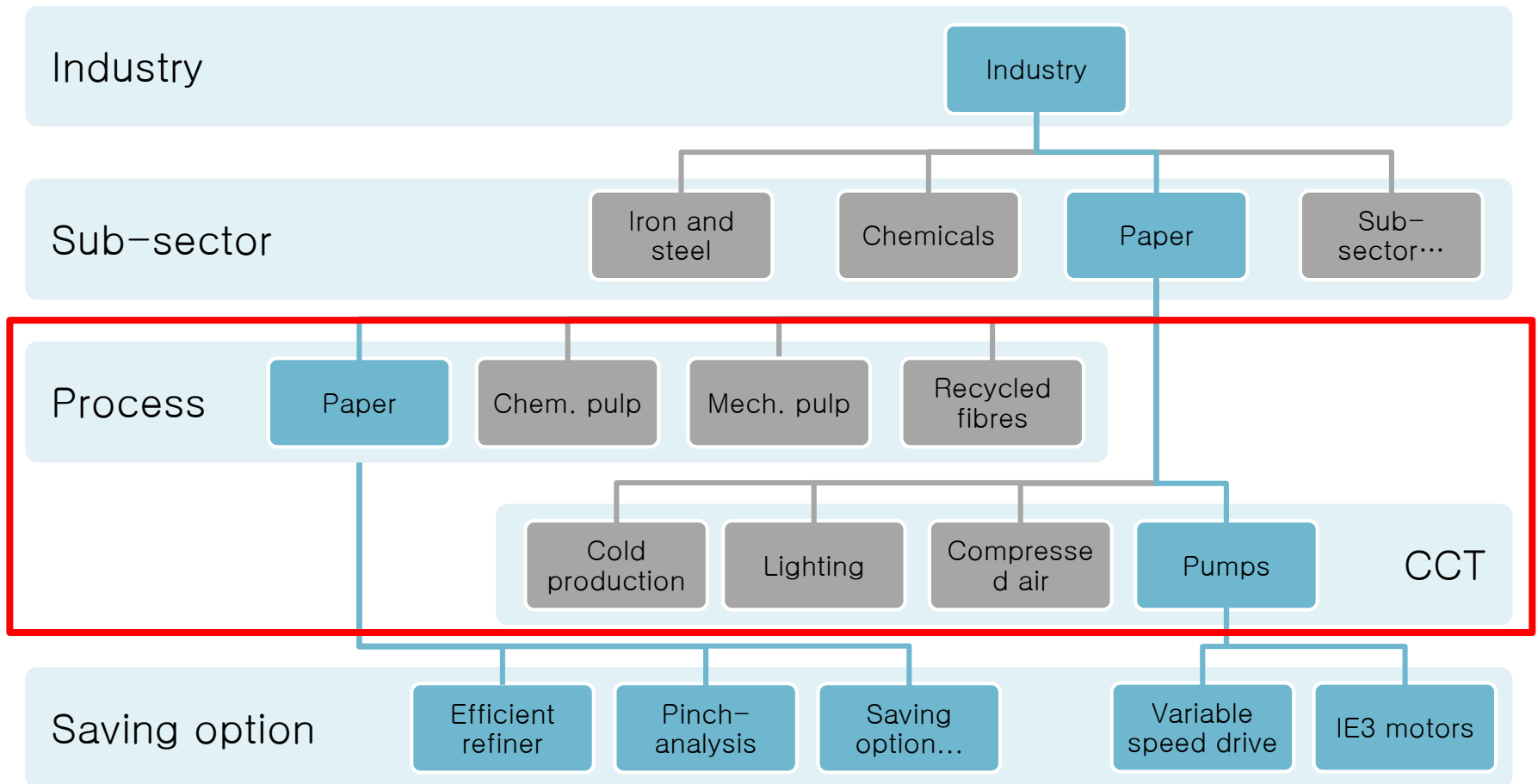
- To be found across all sectors
- Lighting, motors, pumps, fans, compressed air, etc



Sector	Process	CCT
Iron and steel	Yes	Yes
Non ferrous metals	Yes	Yes
Paper and pulp	Yes	Yes
Non metallic minerals	Yes	Yes
Chemicals	Yes	Yes
Food, drink and tobacco	Partly	Yes
Engineering	No	Yes
Others	Partly	Yes



Hierarchical structure of Forecast Industry



Example II: Energy system/ power sector optimization modelling with enertile

- **Integrated optimization of investments and dispatch**

Enertile optimizes the investments into all major infrastructures of the power sector, including conventional power generation, CHP, renewable power technologies, cross-border transmission grids, flexibility options, such as demand-side-management and power-to-heat storage technologies. The model chooses the optimal portfolio of technologies while determining the utilization of these for in all hours of each analysed year

- **High spatial coverage**

The model currently depicts and optimizes Europe, North Africa and the Middle East. Each country is usually represented by one node, although in some cases it is useful to aggregate smaller countries and split larger ones into several regions. Covering such a large region instead of single countries becomes increasingly necessary with high shares of renewable energy, as exchanging electricity between different weather regions is a central flexibility option.



Example II: Energy system/ power sector optimization modelling with enertile

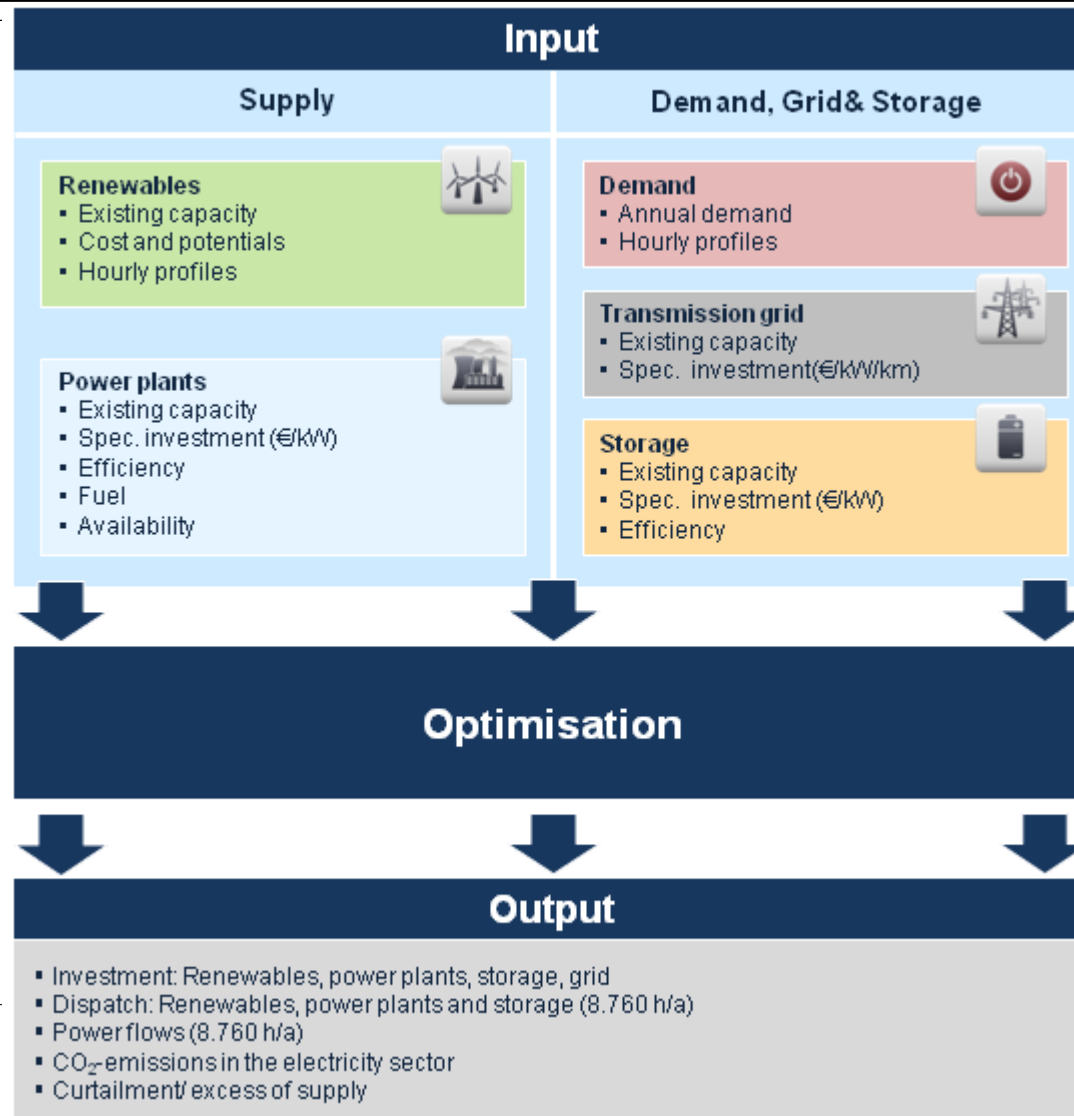
- **High temporal resolution**

The model features a full hourly resolution: In each analysed year 8,760 hours are covered. Since real weather data is applied, the interdependencies between weather regions and renewable technologies are implicitly included.

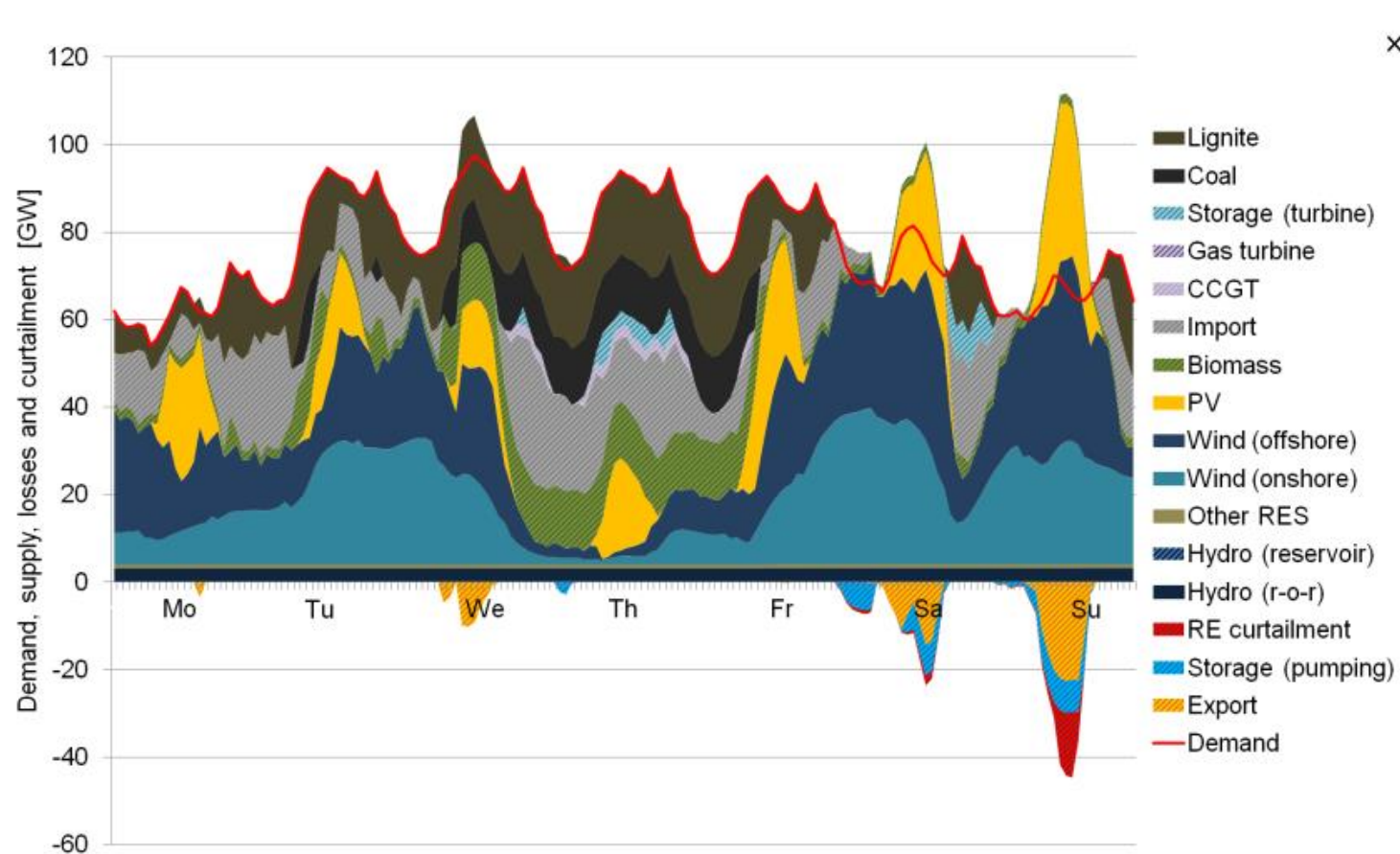
- **Detailed picture of renewable energy potential and generation profiles**

The potential sites for renewable energy are calculated on the basis of several hundred thousand regional data points for wind and solar technologies with consideration of distance regulations and protected areas. The hourly generation profile is based on detailed regional weather data.

Simplified structure of the enertile model



Enertile – example of results: hourly matching of supply and demand

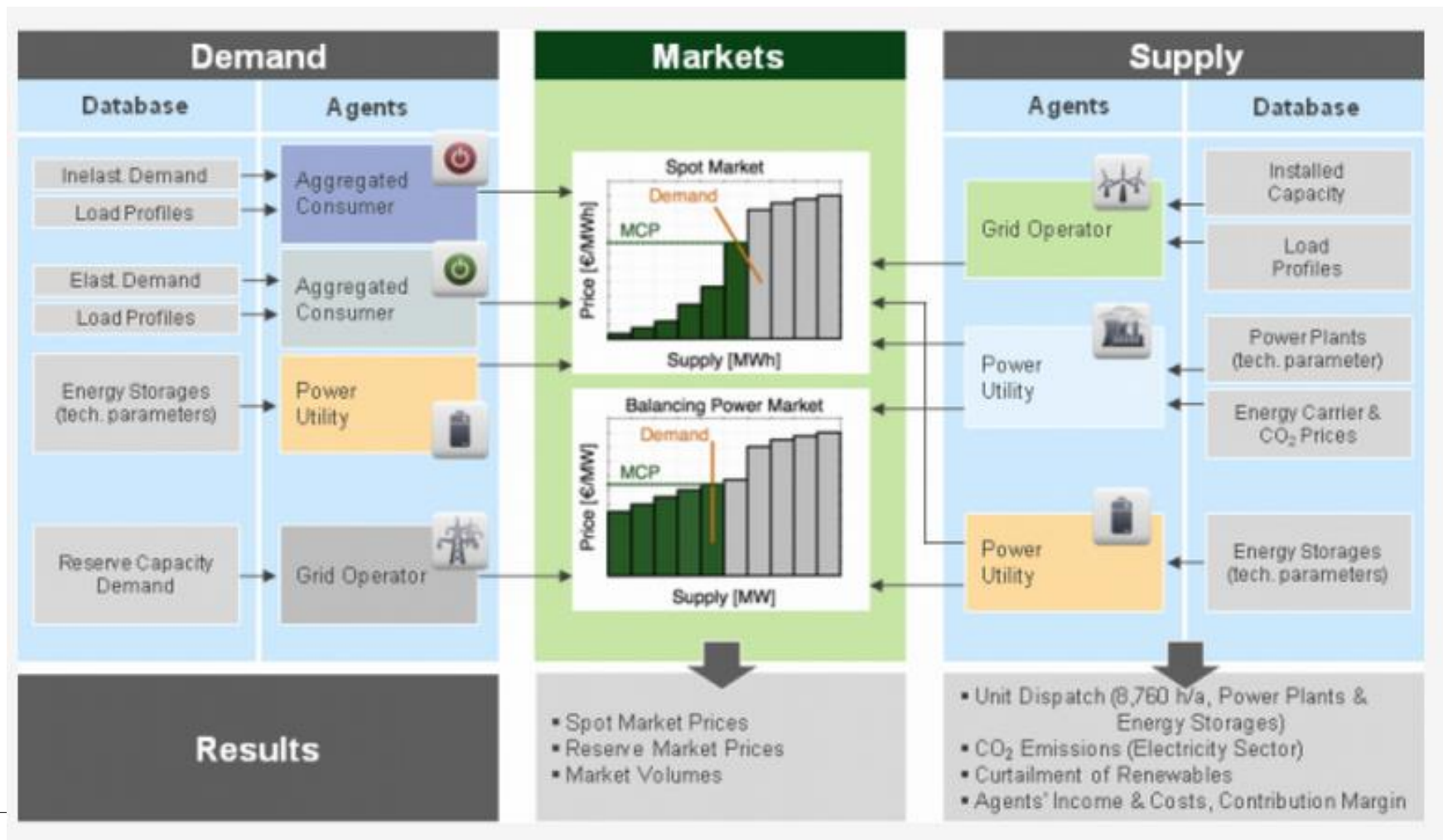


Example of the hourly matching of supply and demand.

Enertile optimisation model: geographical and time resolution

Category	Parameter	Enertile 1	Enertile 2	Enertile 3	Enertile 4	Enertile 5	Enertile 5.1
Scope	Germany	✓	✓	✓	✓	✓	✓
	Europe	✓	✓	✓	✓	✓	✓
	MENA	•	✓	✓	✓	✓	✓
	Flexible regions	•	•	•	•	✓	✓
Resolution of results for renewable technologies	Results on country level	✓	✓	✓	✓	✓	✓
	Results on a grid < 50 km	•	•	✓	✓	✓	✓
	Results on a grid < 10 km	•	•	•	✓	✓	✓
Time resolution	Representation of one year	8760 h	8760 h	8760 h	8760 h	8760 h	8760 h

Enertile simulation model – modelling of electricity prices and market volumes

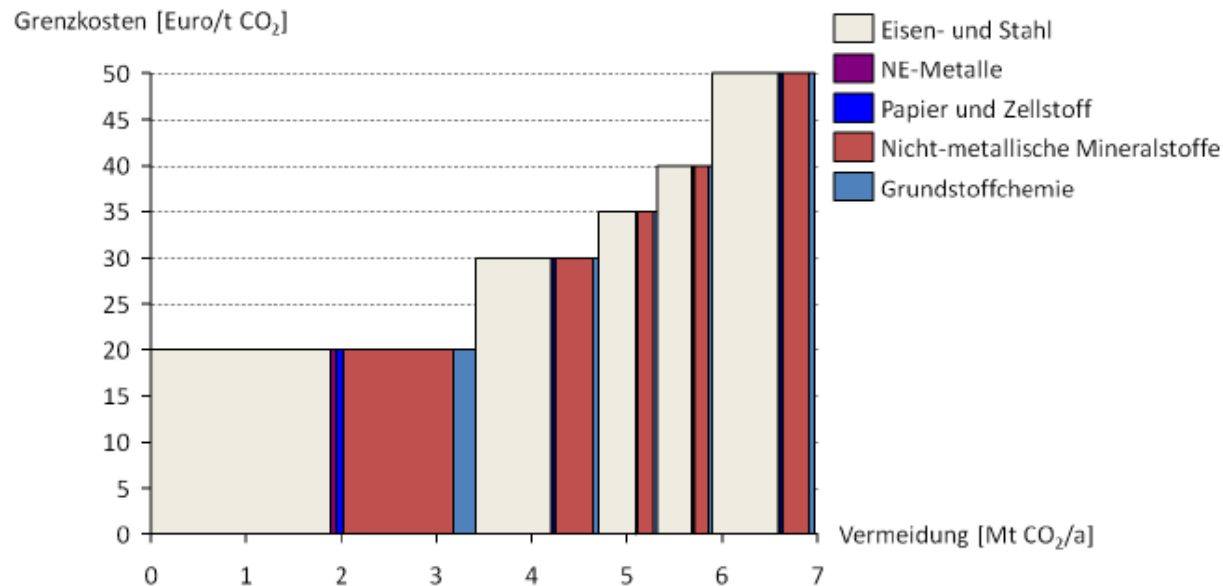


Developing marginal abatement cost curves from techno-economic models

Bottom-up models can be used to develop MACCs

- Running a model (either bottom-up or top-down) several times with different CO₂-prices/restrictions and plot results in one curve
 - No transparent information on technologies behind the abatement potentials
 - Better consideration of system aspects
 - Better consideration of reference systems
- But: much attention should be given to the definition of the scenarios used as they define the form of the marginal abatement cost curve to a large extent

Development of a MACC for the industry sector in Germany with Forecast



- MACC for industry in Germany for 2021–2030
- Labelling of abatement potential in different sectors and for different technology groups
- Shows only abatement potentials for a CO₂ price
- Abatement in the BAU scenario compared to 2010: 16,8 Mt CO₂e
→ not shown in the MACC!

Development of MACCs with Forecast industry and Enertile

- Current project: development of MACCs with Forecast industry and enertile for the EU ETS, all sectors, all countries

- Challenges:
 - Combination of different modelling philosophies from different models (e.g. simulation vs. optimization, myopic vs. perfect foresight, ...)
 - Definition of the reference scenario, in particular definition of policies in the reference scenario
 - Handling of abatement potential coming from other factors such as energy price development
 - Handling of modelling interaction
 - Scope of models to match scope of the ETS

Development of MACCs with Forecast industry and Enertile

Framework data

- Economic development for each sub-sector
- Production per process
- Energy prices on the world market



Power sector



El prices



Industry sector

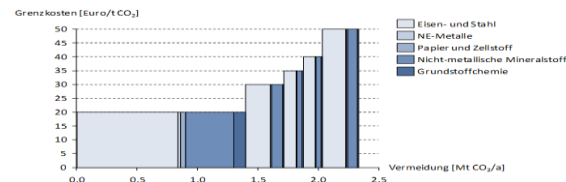


Technology data

- RES potentials
- Power plants park

Technology data

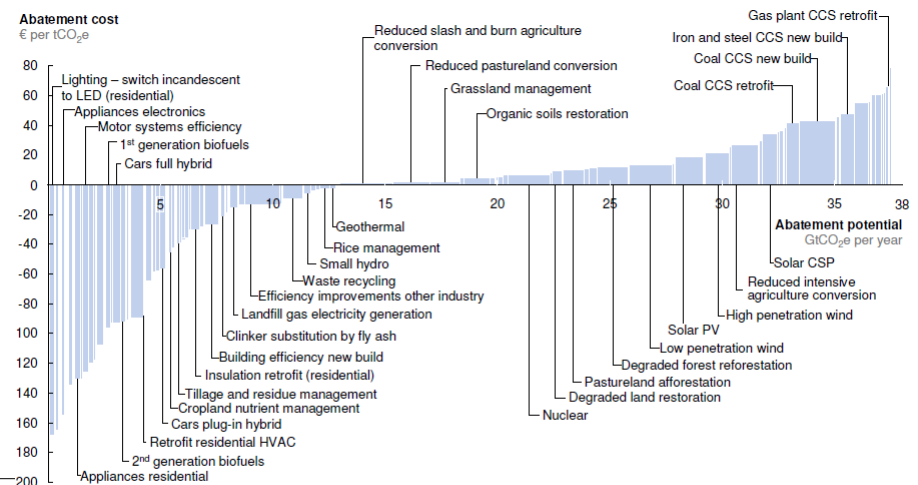
- Energy intensive processes and mitigation potentials
- Steam generators and industrial CHP plants



Wrap up

Wrap up I

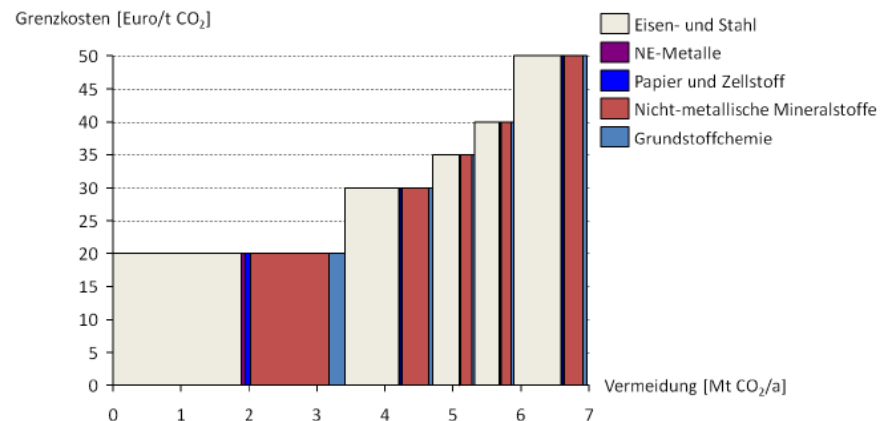
- Quantitative modelling helps in designing and evaluating an ETS as well as in developing trading and abatement strategies
- Different questions from different actors can require very different models
- McKinsey type marginal abatement cost curves illustrate abatement potentials but:
 - knowledge on underlying factors is required to interpret the curve
 - Systemic aspects are not taken into account



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €80 per tCO₂e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.1

Wrap up II

- Techno-economic modelling
 - provides a very systematic way of using technological abatement information as provided in McKinsey type MACCs
 - Definition of alternative scenarios and comparison of scenarios allows answering many questions with specific focuses
 - Handling of models is complex and needs time
- Development of MACCs from techno-economic models by running the model several times with different CO₂ prices possible
 - No transparent information on technologies behind the abatement potentials
 - Better consideration of system aspects
 - Better consideration of reference systems
 - A lot of attention should be given to the definition of the scenarios



Thank you for your attention!

Dr. Vicki Duscha

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