Energy efficiency and carbon dioxide emissions in energy-intensive industry under stringent CO_2 policies

-Comparison of top-down and bottom-up approaches and evaluation of usefulness to policy makers

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Energy Pathways Flagship Program

Presentation outline

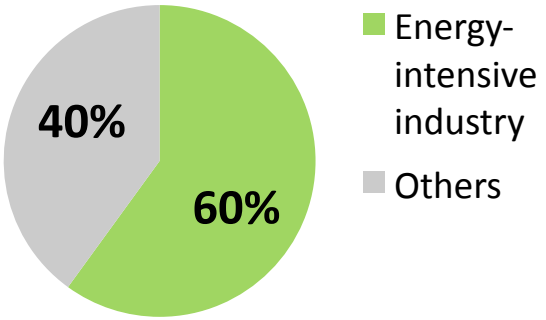
- Introduction: Why is this work important?
- Comparison of bottom-up, top-down, and hybrid approaches
- Presentation of the 5 analysed articles
- Evaluation of usefulness of models to policy and decision makers
- Summary: What are the main findings of this work?

Introduction

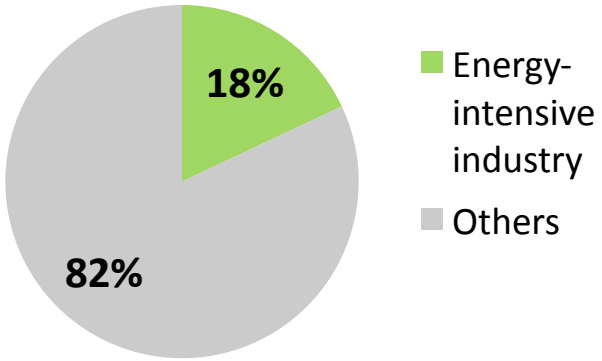
-Why is it interesting to study the energy-intensive industry?

- The energy-intensive industry is a major player in the European energy system

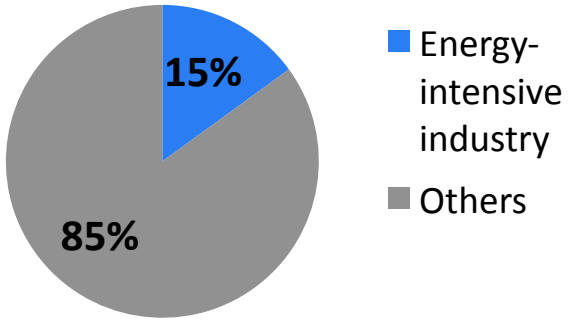
Total energy use in industry, EU27



Total energy use, EU27



Total emissions of CO2, EU27



Source: European Energy and Transport Trends 2008

Introduction

-Special features of the energy-intensive industry

- Comprised of a limited number of (large) plants
  - ~100 refineries
  - ~400 large pulp and paper mills
  - ~40 large integrated steel works with blast furnaces
- Capital intensive
  - Reduced emissions beyond a certain point require large investments and possibly also radical process changes

Introduction

-How is the energy-intensive industry usually studied?

- Traditionally either top-down or bottom-up approaches have been used to analyse the influence of specific policies
- Divergent cost estimations => suggest different policies for meeting climate targets

Introduction

-The aim of this study

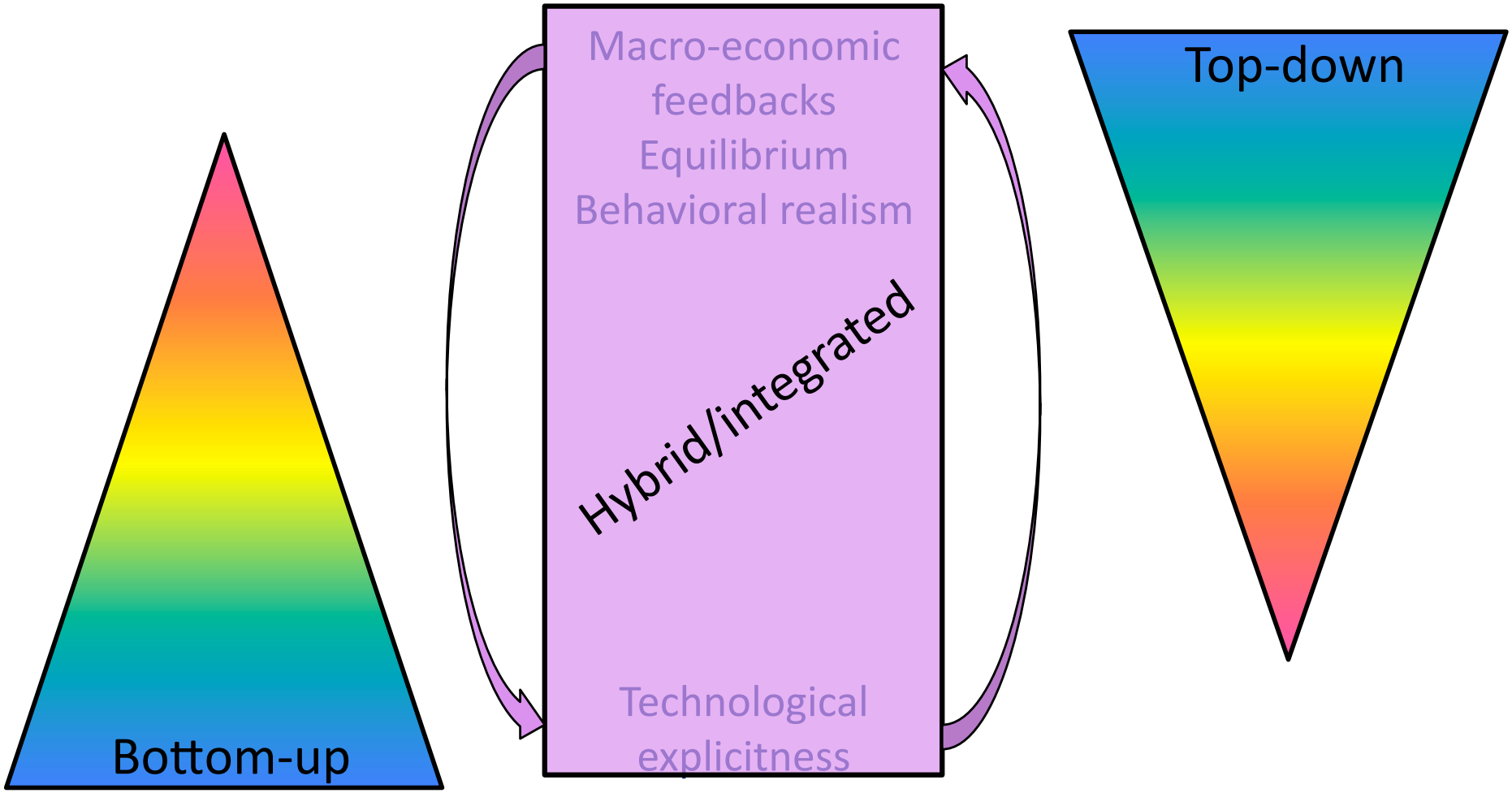
"Analyse and compare top-down, bottom-up and integrated (hybrid) approaches used for evaluating potentials for CO2 emissions reduction and CO2 policy analysis in energy-intensive industry"

Evaluate the usefulness to policy and decision makers

Focus on the pulp and paper industry

Comparison

- General description of approaches



Comparison

- Studies used for the analysis

- Five studies used as examples for the analysis
  - *Heat integration opportunities in an average Scandinavian fine paper mill: model study and comparison with a market pulp mill*, Axelsson and Berntsson (2007); **techno-economic evaluation, conventional bottom-up**
  - *Excess heat from kraft pulp mills: Trade-offs between internal and external use in the case of Sweden—Part 2: Results for future energy market scenarios*, Jönsson et al. (2008); **techno-economic optimization, conventional bottom-up**
  - *The impact of increased efficiency in the industrial use of energy: A computable general equilibrium analysis for the United Kingdom*, Allan et al. (2007); **conventional top-down**
  - *Capital vintage and climate change policies: the case of US pulp and paper*, Davidsdottir and Ruth (2004); **hybrid, top-down framework**
  - *Hybrid modeling of industrial energy consumption and greenhouse gas emissions with an application to Canada*, Murphy et al. (2007); **hybrid, bottom-up framework**

Evaluation

- Usefulness of models to policy and decision makers

- Three key criteria for the evaluation of usefulness of a model for policy makers (Murphy et al 2007)
  1. Technological explicitness
  2. Behaviour realism
  3. Equilibrium feedbacks

Evaluation

- Usef[illegible] of models to policy ar[illegible]

1. Tech[illegible]xplicitness

[illegible]tics

Tec[illegible]s [illegible]oundi[illegible] t[illegible]

Technolog[illegible]s availa[illegible]n the mark[illegible]t

But does not capture the surrounding infrastructure

Captures the surrounding infrastructure to some extent

No explicit technology description

At a relatively aggregated level (products and fuels)

Explicit, but not as detailed as the conventional bottom-up studies

Approach (Study)	Bottom-up approach – techno-economic evaluation (Axelsson and Berntsson 2007)	Bottom-up approach – techno-economic optimization (Jönsson et al. 2008)	Top-down approach – computable general equilibrium (Allan et al. 2007)	Hybrid approach – top-down framework (Davidsdottir and Ruth 2004)	Hybrid approach – bottom-up framework (Murphy et al. 2007)
Technological explicitness	**Very high**	**Very high**	**Very low**	**Medium**	**High**

Evaluation

- Usefulness of models t

2 Behavior realism

– Perfect

Uses demand elasticities. No explicit representation of intangible costs and market heterogeneity

Do not consider intangible costs or non-financial preferences

Assumes neo-classic behaviour functions. Does not include e.g. imperfect information and transaction costs

Technology choice algorithm that explicitly represents implicit discount rates, intangible costs, and heterogeneity in the market place

Approach (Study)	Bottom-up approach – techno-economic evaluation (Axelsson and Berntsson 2007)	Bottom-up approach – techno-economic optimization (Jönsson et al. 2008)	Top-down approach – computable general equilibrium (Allan et al. 2007)	Hybrid approach top-down framework (Davidsdottir and Ruth 2004)	approach – bottom-up framework (Murphy et al. 2007)
Behavioural realism	**Low**	**Low**	**Medium**	**Medium**	**High**

Evaluation

- Usefulness of models to r

Uses macro-economic framework but does not explicitly include equilibrium feedbacks

Conventional bottom-up models = no linkage to the rest of the economy

Based on a computable general equilibrium model

Yes, but does not equilibrate government budgets and markets for employment etc.

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Ability to capture equilibrium feedbacks	**None**	**None**	**High**	**None**	**Medium**

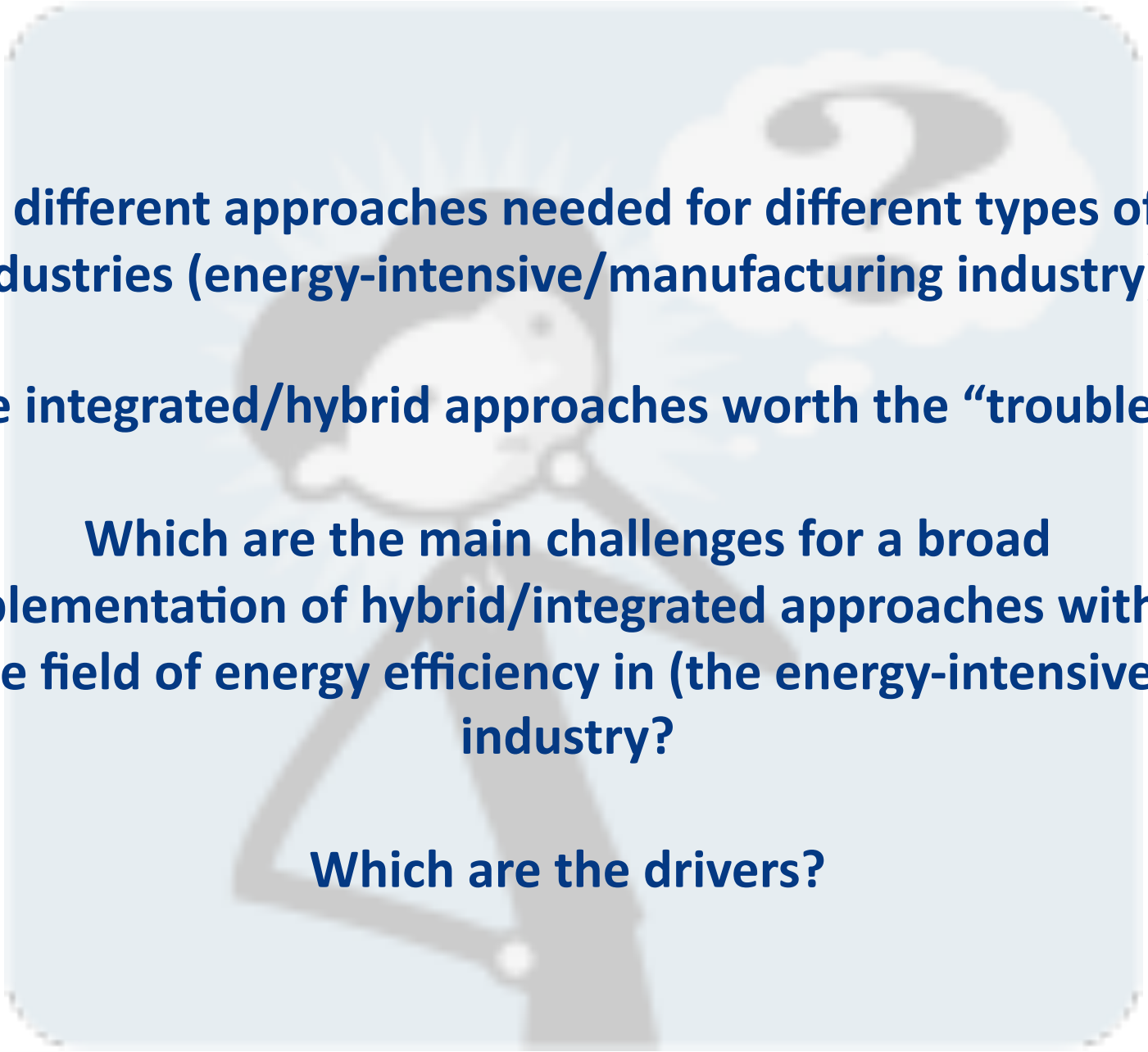
Conclusions

-What are the main findings of this work?

- The pulp and paper industry has many special features
  - Few distinctly different mills and many new, emerging technology options => bottom-up approach is needed
  - A major player in the European energy system => top-down approach is needed
  - The industry does not implement all profitable investments suggested by researchers => behavioural realism is important
- Conventional approaches are limited in providing information to policy and decision makers
  - → Hybrid/integrated models need to be further developed and applied
- Hybrid/integrated models are usually more complex
  - → Soft-linking of conventional contrasting models may be an alternative fruitful approach

Thank you for listening!

Questions?



Is different approaches needed for different types of industries (energy-intensive/manufacturing industry)?

Are integrated/hybrid approaches worth the “trouble”?

Which are the main challenges for a broad implementation of hybrid/integrated approaches within the field of energy efficiency in (the energy-intensive) industry?

Which are the drivers?

	Bottom-up approach – techno-economic evaluation (Axelsson and Berntsson 2007)	**Bottom-up approach – techno-economic optimization (Jönsson et al. 2008)**	**Top-down approach – computable general equilibrium (Allan et al. 2007)**	**Hybrid approach – top-down framework (Davidsdottir and Ruth 2004)**	**Hybrid approach – bottom-up framework (Murphy et al. 2007)**
Approach and method	Bottom-up Process simulations based on mass and energy balances	Bottom-up Optimization based on mixed-integer linear programming (MIND)	Top-down Computable general equilibrium model (UKENVI)	Hybrid w. top-down framework Macro-econometric model with capital vintage	Hybrid w. bottom-up framework Explicit representation of technology, real-market behaviour and equilibrium feedbacks
Scope and resolution	Model mills representing typical Scandinavian mills	Model mills and district heating systems located near the mills	UK economy	US pulp and paper industry, disaggregated into 8 regions	Canadian economy with focus on the industry sector
Type of research questions – *examples*	How does the implementation of a certain technology affect the resulting energy balance and economics of a pulp/ paper mill?	How do energy market prices affect which investments are economically preferable and consequently CO_2 emissions?	How large are the rebound effects for improvements in energy efficiency in a developed economy?	What would be the response of pulp and paper industry in terms of its energy use and CO_2 emissions to different policy measures aiming at abating greenhouse gas emissions?	What would be the response of industry in terms of its energy use and CO_2 emissions to an economy-wide greenhouse gas reduction policy (e.g. tax or cap-and-trade scheme)?
Type of results – *examples*	Energy balance of the studied process and the corresponding economics are affected for changes in specific process parameters and/or energy prices.	Identifies the set of investments that yields the lowest system cost. Emissions and new energy balance are presented.	Economy-wide descriptions of energy use and CO_2 emissions in response to price-based policy measures or exogenous technology assumptions	Scenarios of mid to long-term industrial energy use and CO_2 emissions in response to different policy measures	Scenarios of mid to long-term industrial energy use and CO_2 emissions in response to different policy measures (economy-wide price-based instruments)
Decision maker target group	Decision makers in industry	Decision makers in industry Policy makers	Policy makers	Policy makers	Policy makers
Technological explicitness	Very high	Very high	Very low	Medium	High
Behavioural realism	Low	Low	Medium	Medium	High
Ability to capture economy-wide equilibrium feedbacks	None	None	High	None	Medium

Evaluation

- Usefulness of models to policy ar

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- Usefulness of models to policy and decision makers

3. Equili… feedbacks
   - …
   - …
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Ability to capture equilibrium feedbacks	**None**	**None**	**High**	**None**	**Medium**