DIW BERLIN

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WHITING SCHOOL
of ENGINEERING

EIA Workshop on International Electricity Modeling

Price discrimination, overlapping regulations, and competing objectives

How to model (beyond) the electricity sector?

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1 Current approaches to energy modelling for policy evaluation

Looking at the electricity sector isn't sufficient anymore to understand an increasingly complex energy system

The common approach to energy (electricity) system modelling:

- single optimization model (e.g., TIMES-MARKAL)
- modular approach: individual sector models connected by exchanging price information, converging to a stable solution

Both approaches…

⇒ can be interpreted as equilibria of a perfectly competitive market

⇒ fail to capture many interdependencies and distortions arising out of regulatory measures and climate & energy policy

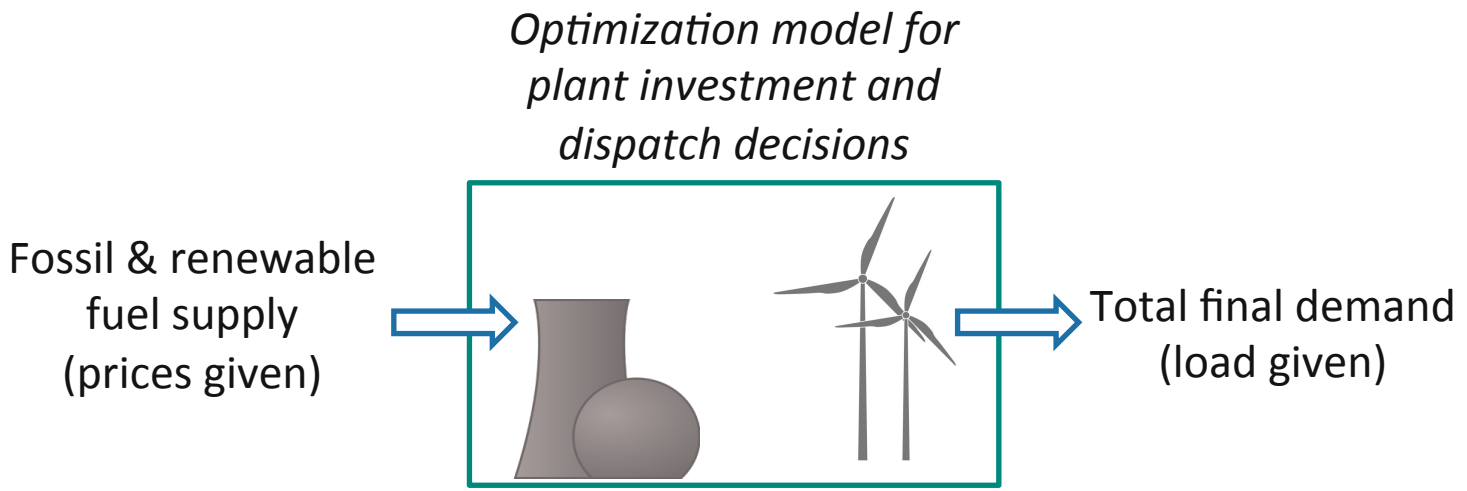
⇒ face the problem of "bang-bang" results

1 The standard electricity sector model

A "plain-vanilla" electricity model for investment & dispatch takes demand and supply as given parameters

The standard electricity sector model:

- ⇒ takes investment costs and fuel (input) costs as exogenously given
- ⇒ minimizes system costs for satisfying a given load profile
- ⇒ can incorporate a lot of detail with regard to technologies



2 On the advantages of multi-player models

Why should we bother about formulating energy models as multi-player games?

- Better understanding of present and future market dynamics through the behaviour (incentives) of individual players

- Improved foundation of projections and scenario analysis

  Augment internal and external validity of numerical results and policy conclusions derived from the model

- We want to build "better" models!

  Many of the complicating features and interdependencies present in electricity markets can be described using simple optimization models

  ⇒ but not all relevant aspects can be captured adequately!

2 On the advantages of multi-player models

Multi-player formulations allow to develop "better models" yielding higher-validity policy conclusions

- Distinguishing between specific players
  - ⇒ different actors in the market have distinct (opposing) objectives, responses to rivals, risk aversion (e.g. discount factors)
- Describing market imperfections
  - ⇒ regulations and incentives may have overlapping/opposing effects
- Gaining modelling flexibility
  - ⇒ prices can be used directly in player's objective function and constraints (e.g., ad-valorem taxes, secondary income streams)

2 On the advantages of multi-player models

Formulating a electricity sector model as a multi-player game offers additional flexibility in model development

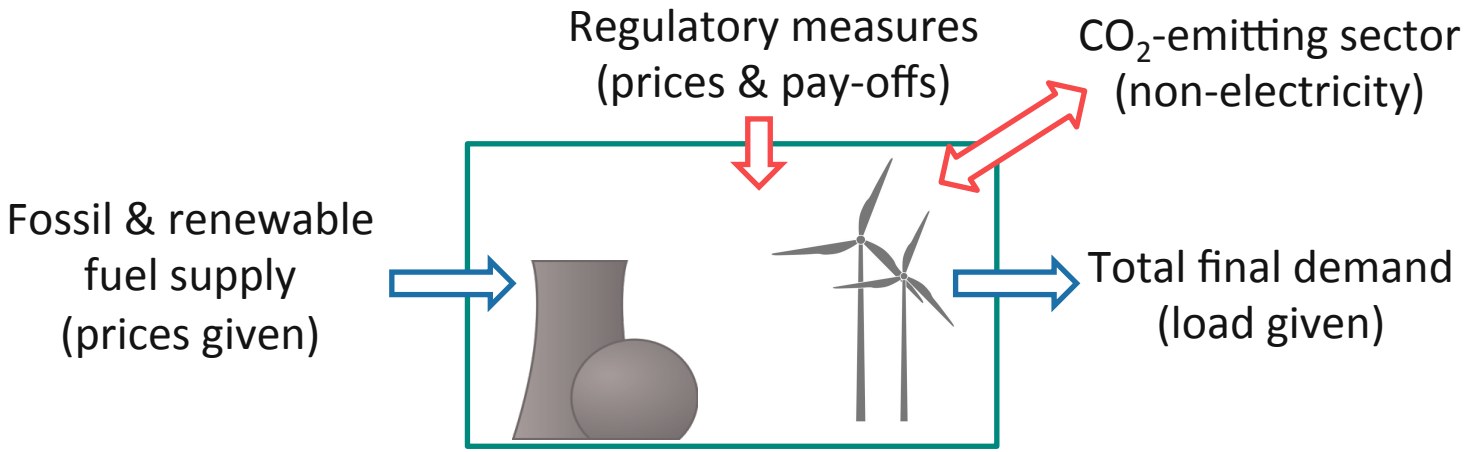
- Flexibility in model development
  - ⇒ more explicit formulation and interpretation of decisions
    e.g., linkages/trade-offs between different players, nested policies
- More levels of freedom in calibration
  - ⇒ market power (conjectural variations) formulation is helpful for calibrating a large model, because it yields diversified sales & trade
- Scalability and ease of model extensions
  - ⇒ easily integrate different models (sectors, fuels, players), and move to multi-level games (i.e., Stackelberg leader-follower)

3 Capturing regulatory intervention in energy models

Renewable energy support and emission reduction measures may have complementary or opposing effects

Regulatory measures introduce distortions from the standard model:

- may target both quantities and prices (via mark-ups, taxes, etc.)
- may affect both investment incentives and dispatch (merit order)
- may have cross-effects and interdependencies with other sectors (e.g., CO_2 emission quota for power sector and industry)



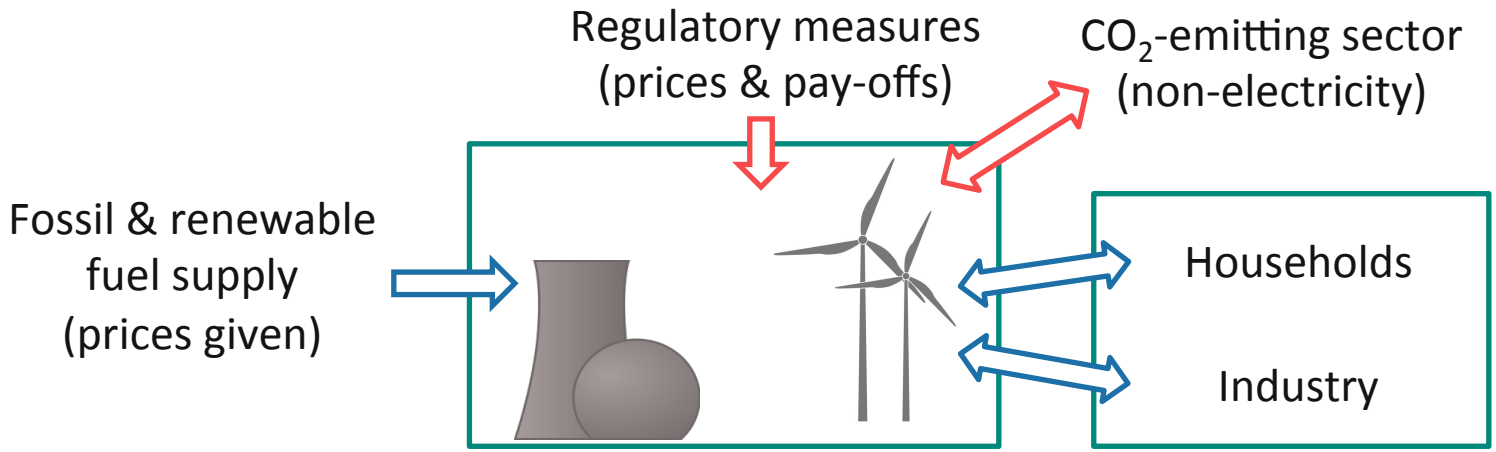
3 Disaggregating the demand side

Demand for electricity is an aggregate of various sectors with very distinct short- and long-term price responses

Electricity demand comprises sectors with distinct elasticities:

- industry is elastic in the short-run, but not so much in the long-term
- households are inelastic short-term, more elastic in the long-run

⇒ price discrimination between consumers or sector-specific levies may be warranted even in competitive and efficient markets

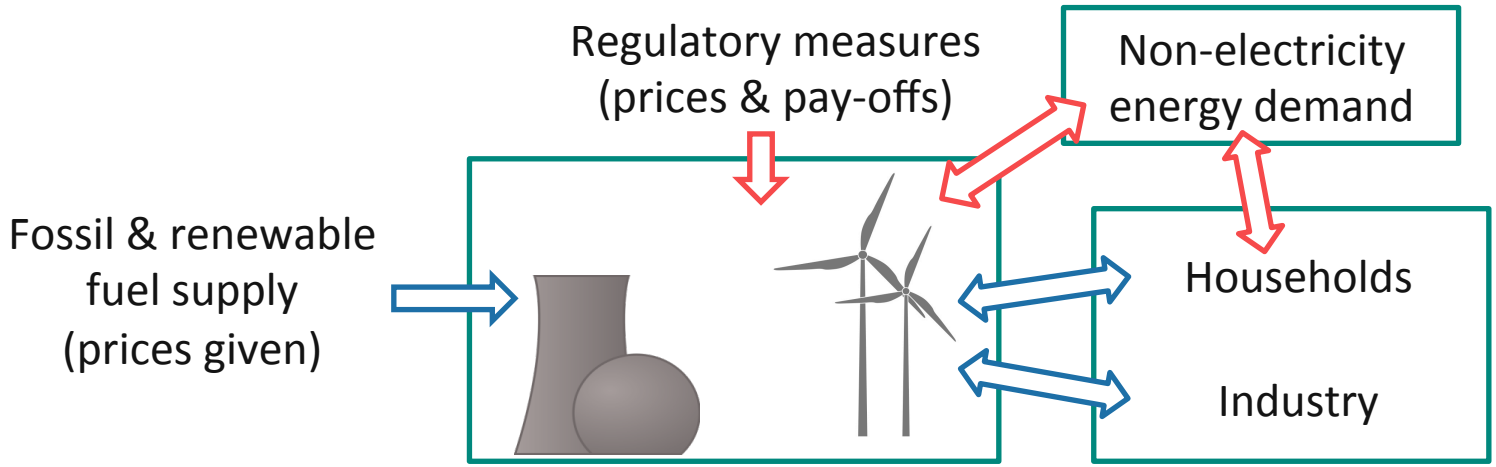


3 Further disaggregating the demand side

Demand-side measures and energy efficiency improvements will require substantial investment in new infrastructure

Energy demand reduction and substitution to low-carbon fuels have the highest potential for emission reduction (IEA, 2014)

- ⇒ economic viability of investments depend on (expectations of) future prices and the alignment of incentives
- ⇒ may require further regulatory intervention to realise potential



3 Considering the impact of the electricity sector on fuel supply

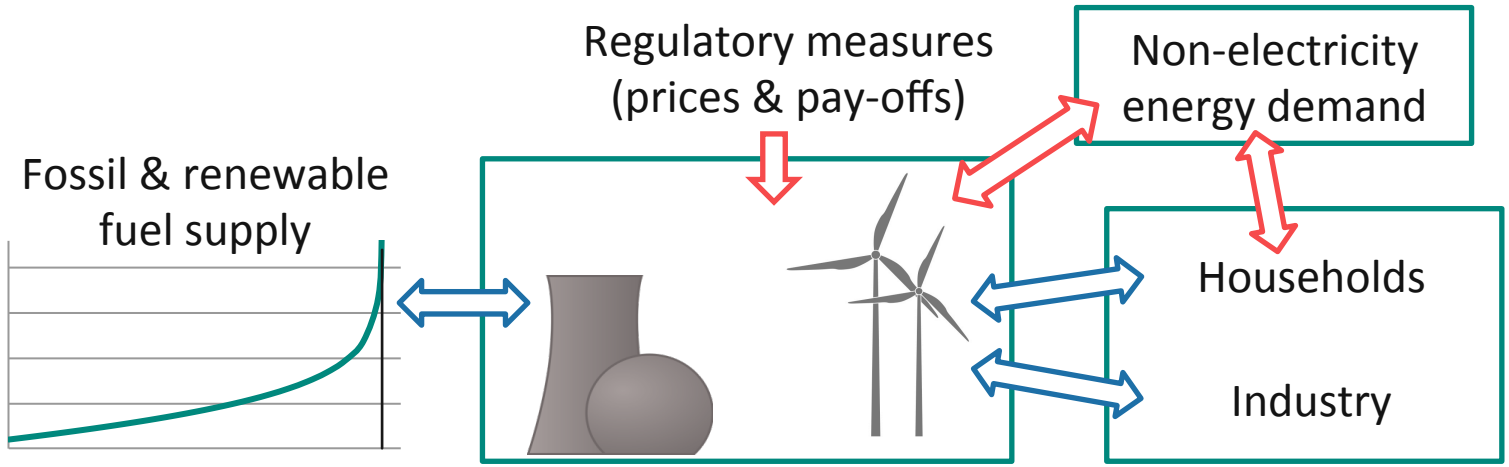
Costs depend on the portfolio of power plants, and high exposure to specific fuels may be politically unacceptable

Global shift to renewables can yield cost savings through learning

⇒ but intermittent renewables require substantial backup capacity

Global shift to natural gas in power generation may lead to increase of price volatility and higher import dependence for some countries

⇒ may trigger intervention due to "security of supply" concerns



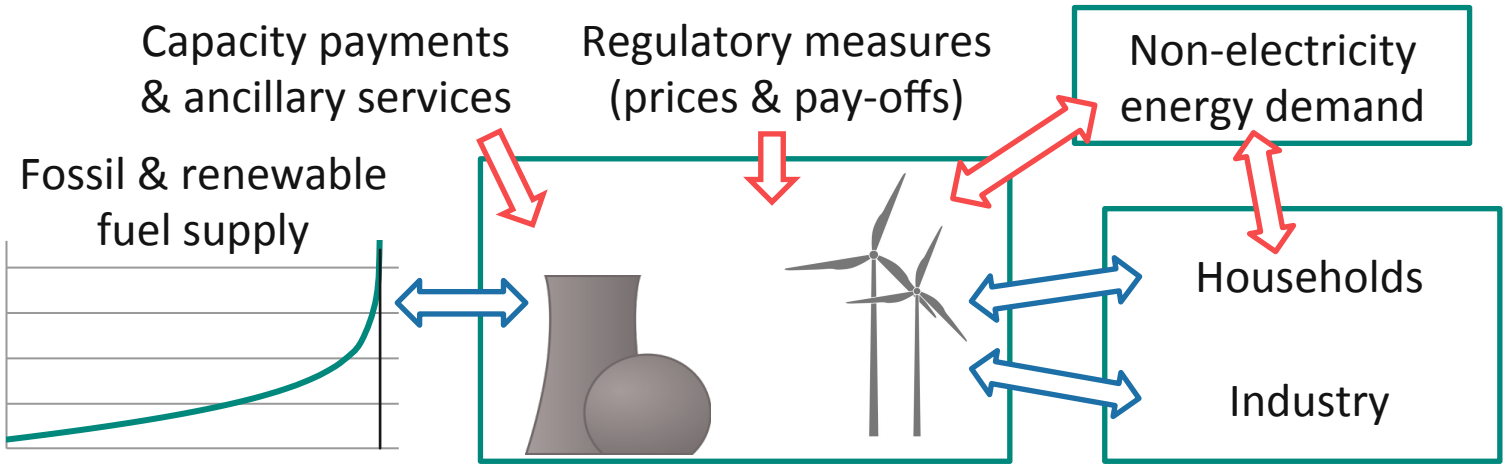
Considering incentives of individual players

Risk aversion, the missing money problem, and the "chicken and egg" dilemma confound investment decisions

Investments along the value chain often suffer from uncertainty and a first-mover problem (e.g., roll-out of electric vehicles, power storage)

⇒ additional funding streams are necessary to incentivise investment

⇒ capacity payments and markets for ancillary services offer an opportunity for stable revenue when wholesale prices are too low



3 Personal recommendation for EIA's new electricity sector model

A state-of-the-art electricity sector model needs to capture distinct player incentives and the many policy dimensions

- Interaction of the electricity sector with fossil and renewable fuel supply needs to be accounted for beyond today's modular "price-based" approach
- Interdependencies and interaction of climate & energy policy have to be modelled beyond quantity-based models
- Incentives of individual players must be considered explicitly, in particular risk aversion, the missing money problem and the "chicken-and-egg" dilemma

Thank you very much for your attention!

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