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MODELLING ELECTRICITY SUPPLY AND DEMAND UNDER NEW MARKET DESIGNS

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Outline

I. Challenges for electricity planning

- I.1 New market design

II. Electricity scenarios modelling

- II.1 Generation and transmission planning
- II.2 Demand and supply planning

III. Summary and avenues for further research

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Challenges

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Transition towards a low-carb n economy

Growing role for r sources.

Electr port and other rend.

Incre g role of the consumers:
Demand response
Prosumers

Electricity

New approaches to electricity nning

New electricity ma

Adaptatio astructures and a

New models towards low-carbon chnologies

Modelling

Security of supply
Costs for households and industry under control
Public acceptance

Challenges

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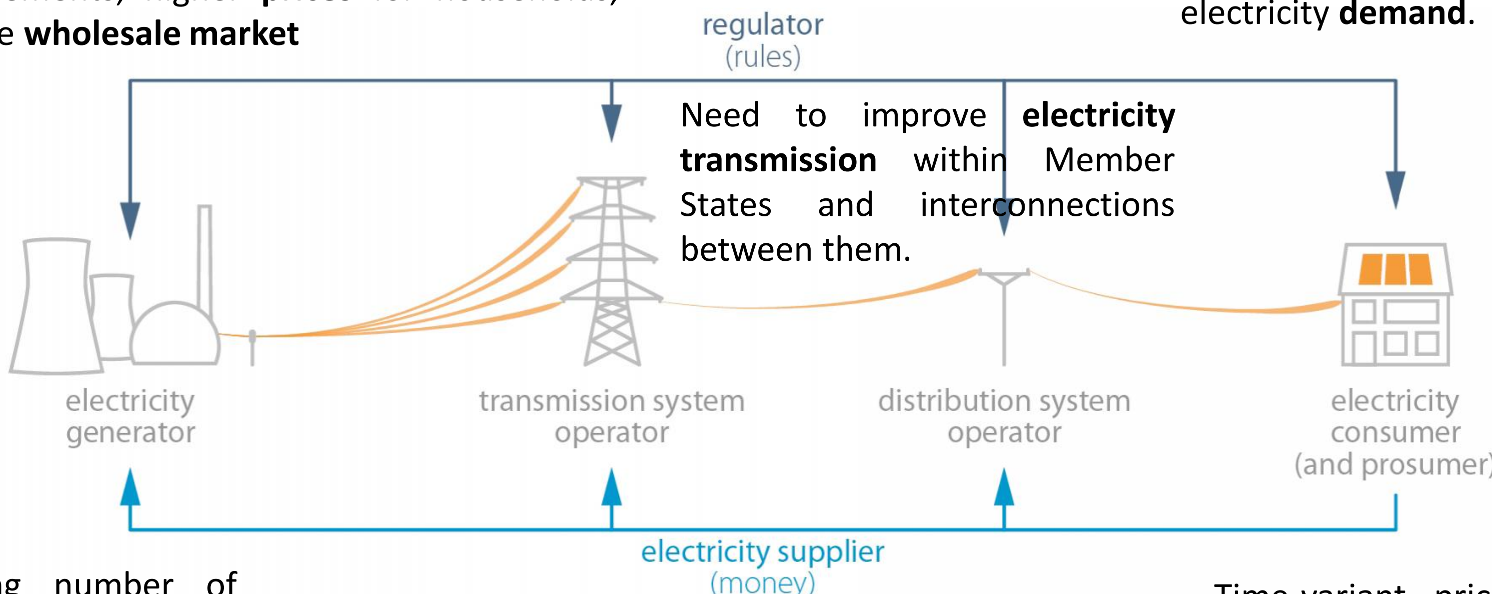
The increasing share of distributed and variable **renewables** (solar, wind) can lead to: new **transmission** capacity requirements, higher **prices** for households, low prices in the **wholesale market**

Further electrification of the economy leads to rising electricity **demand**.

Need to improve **electricity transmission** within Member States and interconnections between them.



The increasing number of **prosumers** can lead to **demand** reduction and decreased revenues for **grid operators**, which can lead to higher **prices** for consumers.

Innovative business models in **electricity markets** (energy service companies, virtual power plants – aggregators)

Time-variant pricing could give consumers an incentive **demand response**

Technological developments, such as smart appliances and smart grids, electricity storage, electric vehicles

Source: adapted from European Parliament (2016)

New market design

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Diversification (security of supply);

Environmental impacts (energy efficiency, renewables, new technologies – RES, CCS…);

Competitiveness (low prices + internal energy resources + smart energy management)

Human interaction becomes a large part of the system – "prosumer" (V2G, RES…);

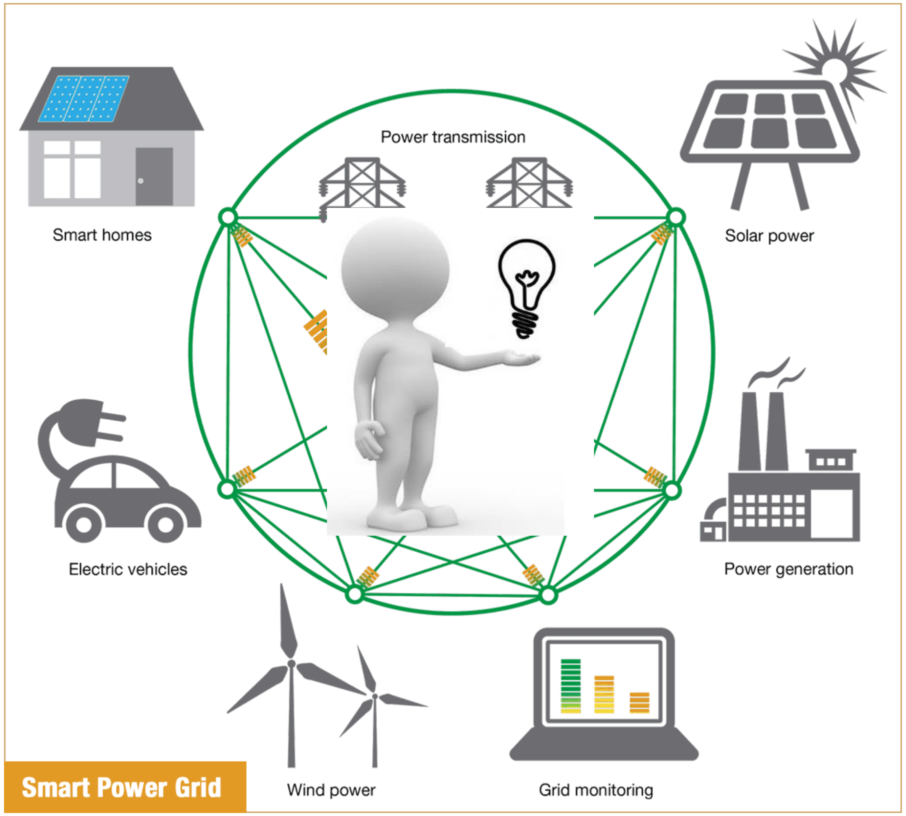
Social acceptance and consumer engagement in the system (and market)

ICT is a crucial element for data management;

"Smart energy" products, services, businesses …

(…)

The grid of the (very near) future



http://www.news.gatech.edu/features/building-power-grid-future

New market design

Proposal for a Regulation of the European Parliament and of the Council on the internal market for electricity (November 2016)

New energy market design			
Prosumers	Renewables	Storage	Demand response

- ✓ New market opportunities and increased competition on retail markets.
- ✓ Aggregation of generation and demand to enable consumers and small businesses to participate in the market.
- ✓ Remove barriers to cross-border electricity flows and cross-border transactions.
- ✓ Encourage regional cooperation, allow for progress in research and development, enable the efficient dispatch of generation and demand response.
- ✓ Promote liquid short-term markets and long-term price signals.
- ✓ (…)

Electricity scenarios modelling

Electricity scenarios modelling

Some key aspects

- ✓ Electricity system is more than a collection of interlinked technologies and stages. The dynamics across the electricity value chain must be considered – **“co-optimization”**;
- ✓ Planning **across time scales** to account for short term dynamics of renewable generation and long term perspectives;
- ✓ **Flexibility** as requisite for RES systems: flexible generation, storage, demand response and interconnection (Verzijlbergh et al, 2017).
- ✓ Understanding and modelling **energy-related behavior** and consumers participation in the electricity market.

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Generation and transmission planning

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Generation and transmission are two main components of the power systems and different models and approaches have been used to design and evaluate their expansion possibilities.

The generation expansion planning (GEP) and transmission expansion planning (TEP) problems are frequently addressed separately:

- ✓ independent complex mathematical models;
- ✓ solutions that may not be optimal from an integrated power systems perspective even under free market conditions.

Generation and transmission planning

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TEP has typically been addressed by a reactive approach, where the transmission planner responds to committed generation expansion projects.

Co-optimization with GEP can bring considerable economic benefits to the power system while considering the reliability of the system for high RES shares.

Unbundled environment

"transmission planning accounting for market response" or "anticipatory transmission planning."

GEP & TEP → G & TEP

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Generation and transmission planning

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Although various co-optimization tools already exist, the demonstration of advanced co-optimization methods for long-term planning of power system using detailed regional data in a realistic setting and integrating relevant uncertainties at operational time frame, **is still missing** (Krishna et al, 2016).

Co-optimization **can benefit the planning processes** of states and Planning Coordinators regardless of market structure or regulatory regime.

Anticipatory transmission planning is a use of co-optimization to evaluate network investments while considering how generation decisions, both dispatch and investment, will respond to changes in transmission capacity, access, and congestion.

Liu et al (2013)

Generation and transmission planning

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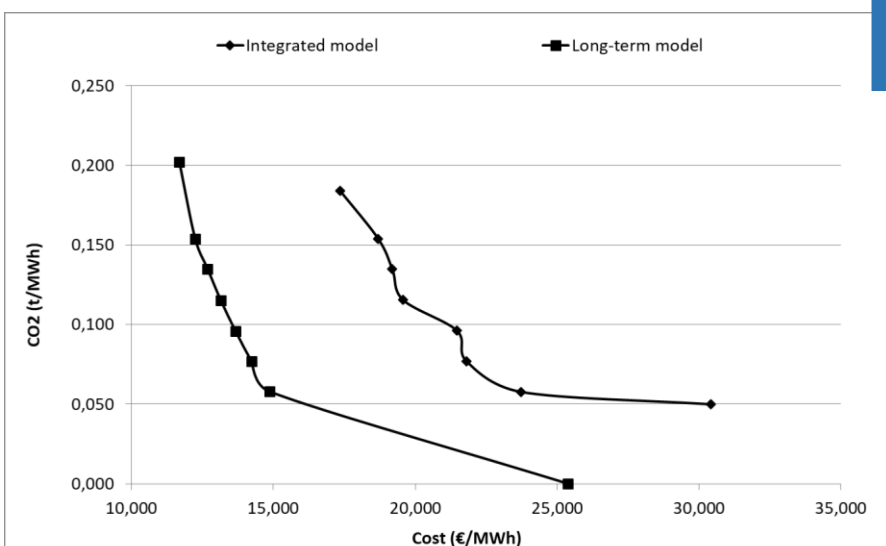
Different studies and models were usec performance of thermal power plan planning (GEP):

Importance of the coordinat decisions in GEP and scenario

.

The variability of RES can create a number of technical challenges in the power system planning and operation:

- load-generation imbalances
- voltage sags
- overloads
- frequency variations



Pereira et al (2017)

The impact of RES variability on the operating conditions and on the generation expansion planning is non-negligible

Electricity supply

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Generation and transmission planning

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RiskModEl -Risk based Modelling for Electricity System Planning

- ✓ Computation of **risk metrics** targeting the assessment of the adequacy of the transmission system under different high RES scenarios – VoLL (value of loss load) and social value of the system adequacy.

- ✓ **Development**/selection/adaptation of **co-optimization models** for long-term G&TEP under uncertainty particularly well suited for high RES systems. Test the models in the Iberian electricity system to assess:

    - ✓ Computational performance
    - ✓ Electricity system performance
    - ✓ Policy implications

Demand and supply planning

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Demand response for flexibility planning

Demand response is frequently seen as an operational issue (**short term**), however its role on long-term generation and transmission (**long term**) must be considered.

- ✓ Demand response can facilitate the integration of variable RES sources
- ✓ Dynamic control of the load should be considered to balance the system and peak control (more frequently addressed)
- ✓ Potential role that demand response can play in RES integration?

Demand and supply planning

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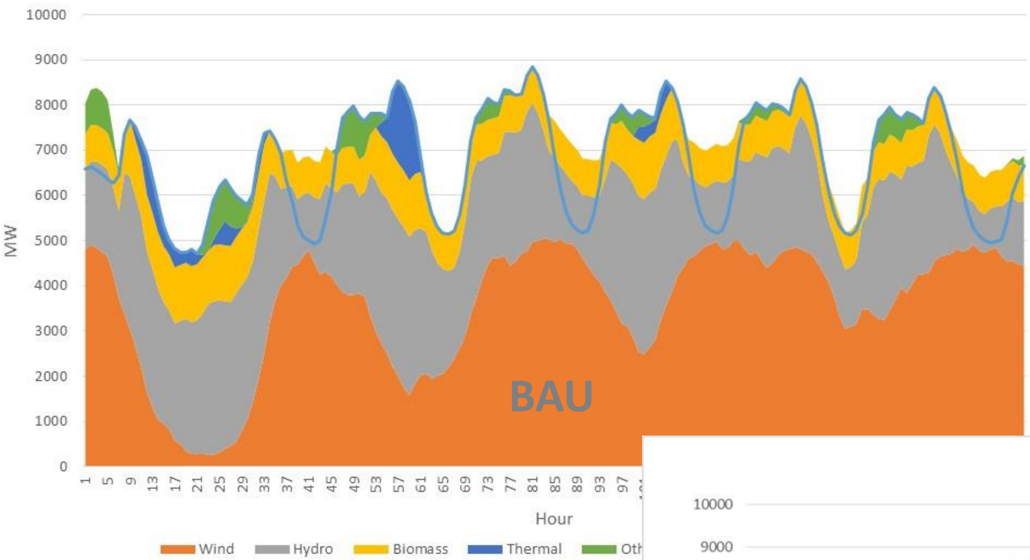
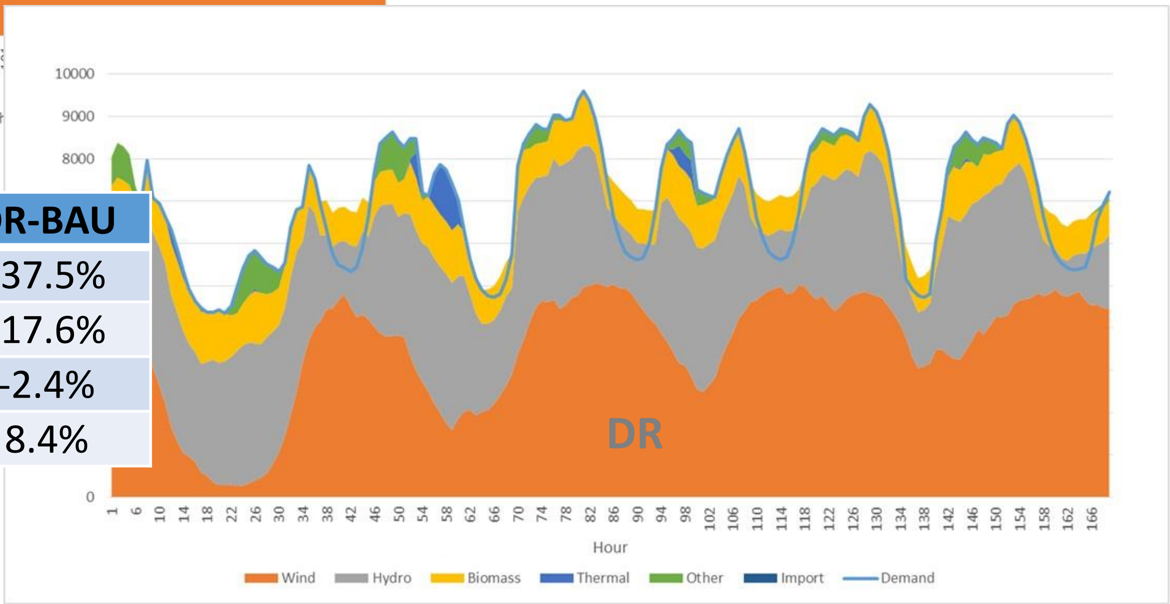


Dynamic response models towards RES

(simulation, example Portugal)

Parameter	DR-BAU
Exportation	-37.5%
Importation	-17.6%
Thermal power production	-2.4%
Maximum load difference*	8.4%



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Effective dynamic DR strategies require an **effective smart system**:

- ✓ Control of intelligent end-use appliances;
- ✓ Data management;
- ✓ Dynamic price models;
- ✓ Strong reliance on ICT;

DR can play an important on adapting electricity system to climate actions and contribute to low carbon pathways **for long term scenarios**.

High RES system

Demand response to be considered on scenarios modelling
Climate change uncertainty for RES and demand profile

GEP & DR → **G & DRP**

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Demand and supply planning

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Demand response for flexibility planning

- ✓ Simulation and optimization modeling to test the relevance demand response for future scenarios for the electricity system – **Dynamic response models towards RES**. Test the models in the Iberian electricity system to assess:
    - ✓ Economic and emissions impact
    - ✓ Climate risk over demand and supply
- ✓ Characterization of consumers awareness, motivations and barriers for adopting more efficient energy behaviors and engaging in demand response programs.

Summary and avenues for further research

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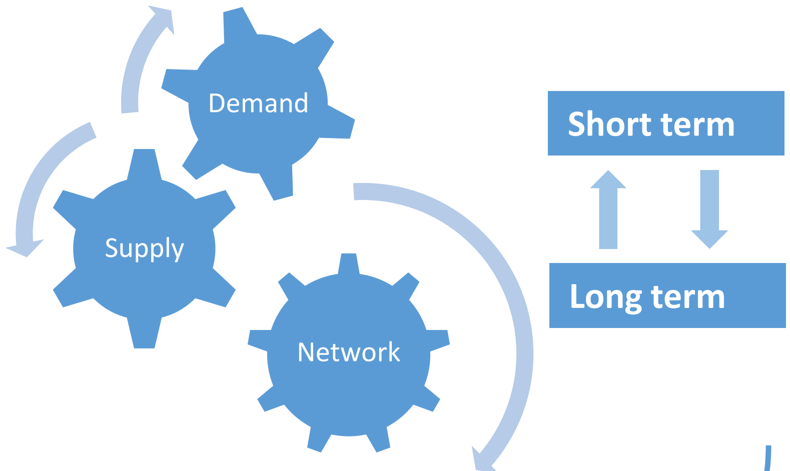
Multidisciplinary perspective

Integrated planning across electricity value chain



Planning across time scales

Planning for uncertainty

Co-optimization
Integrated European perspective
High RES scenarios
New modelling approaches

Social/human factor in the electricity market

Barriers to public participation. How to overcome? Behaviour? Regulators? Policy? Business models?

References

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European Parliament (2016) “Understanding electricity markets in the EU” Briefing, November 2016.

European Parliament (2017) “Internal market for electricity” Briefing, March 2017.

R.A. Verzijlbergh, L.J. De Vries, G.P.J. Dijkema, P.M. Herder (2017) “Institutional challenges caused by the integration of renewable energy sources in the European electricity sector,” Renewable and Sustainable Energy Reviews, Vol. 75, pp. 660-667.

Sérgio Pereira, Paula Ferreira, A.I.F. Vaz (2017) "Generation expansion planning with high share of renewables of variable output", Applied Energy, Vol. 190, 1275-1288.

Krishnan, V; · Ho, J; Hobbs, B; Liu, A; McCalley, J; Shahidehpour, M; Zheng, Q (2016) “Co-optimization of electricity transmission and generation resources for planning and policy analysis: review of concepts and modeling approaches”; Energy Systems, Vol. 7, pp. 297-332.

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COMPETE

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