# Innovative Re-making of Markets and Business Models for a renewable energy system based upon wind power

# IREMB

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A collaborative project between Aalborg University, Copenhagen Business School and Danish Technical University

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## The IREMB approach - Design, intervention, and engaging with stakeholders

IREMB is a collaboration between Aalborg University, the Danish Technical University, and Copenhagen Business School, involving 14 researchers with different forms of expertise, which makes them a unique team: Engineers with expertise in energy systems planning, economists who work with energy market design, as well as transition scholars with expertise in Science, Technology and Society and Economic Sociology.

IREMB is hinged on long-standing Danish ambitions of decarbonizing the energy system. Decarbonizing the existing energy system implies increased reliance on renewable energy sources – notably wind power – but it also poses great challenges to the existing governance arrangements regarding energy production and consumption, investments, and operational practices. Firstly, for the electricity system increased reliance on fluctuating energy sources introduces challenges of balancing power generation and consumption in hitherto unseen ways. The old fossil fuel electricity system was designed to deliver kilowatt-hours in a uni-directional fashion from centralized power plants, and flexibility in balancing electricity generation and demand was achieved by adding or subtracting 'stored fossil fuel' from power plants. The governance paradigm of this old system comprised regulation of technologies and fuels, design of electricity markets, and rules for electricity system operation. It is unlikely that the old governance paradigm can accommodate the flexibility in generation and consumption needed in a low-carbon energy system based upon fluctuating energy sources.

Secondly, the existing governance regime has created a technical and regulative separation of sectors within the energy system – electricity, heat/cooling, mobility, and gas – which further complicates the integration of wind into the energy system and, thus, the transition to a fossil-free energy system. Building an energy system based upon fluctuating energy sources calls for greater flexibility in combining all of these elements in the future energy system, e.g. electrification of Power-to-Heat/cooling, Power-to-Mobility, hourly and season-based storage, and conversion that in a Smart Energy System can increase flexible electricity demand.

Overall, it is a well-established fact that the limits to increased decarbonization lies not in science and technologies, but in the existing governance paradigms. A successful and cost effective decarbonization of the existing energy system requires the design and implementation of new economic-regulatory governance arrangements, e.g. market arrangements, taxes, and investment procedures, that are that capable of ensuring radical technological transformations. Because the decarbonized energy system is constituted by many complementary technologies like wind power-heat-pumps or heat-storage, electrical vehicles, and biomass resources, a coherent technical energy system scenario is important to inform regulations that shape coordination and avoid suboptimal investments. For example if biomass is important for liquid electrofuels, based on hydrogen existing power plants should not use biomass boilers to replace coal boilers.

The IREMB project addresses the inadequacy of the current market governance arrangements in two areas: First, it is well-established that power markets, based on short term marginal cost pricing, fail when large shares of zero-marginal cost wind power are added to the market. The overall spot-market price falls to levels that cannot support investments in capacity. The Nordpool electricity market suffers from this problem too, and needs to be redesigned. The short-term electricity market model secures an operational allocation of generation, with time-resolution in markets split into 'day-ahead-spot', 'intraday' and 'balancing', but the Nordpool market design cannot finance investments in capacity – neither in conventional power plants nor in renewable generation. The challenge facing all electricity markets is to make a design that can allocate and incentivize investments, and this entails reconfiguring existing market and regulatory support schemes. There is, however, no 'perfect' market design that can ensure allocation

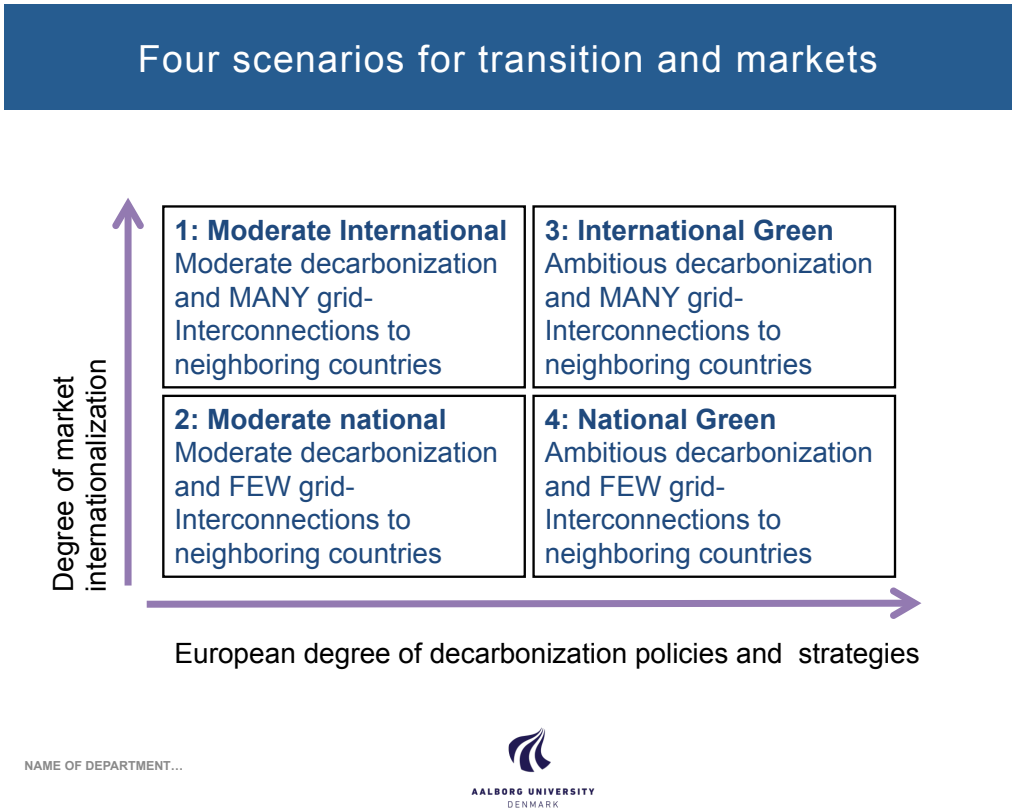
and incentivize capacity and low-carbon investments.

The second problem is that exiting governance arrangements do not support energy system transition through increased electrification of functions like heat/cooling and mobility currently served with fossil fuels. Developing a Smart Energy System with cross-sectorial integration challenges the existing boundaries between electricity, heating, transportation and gas sectors, and requires new economic-regulatory governance arrangements, that can ensure radical technological transformations amongst technologies and infrastructures within the electricity, heat and gas sectors.

The continued decarbonization of the electricity and energy system is a long term process with new technologies, and therefore it is only logical to expect that the associating market governance must evolve and be restructured based on experiences and learning.

## Electricity system futures and how to price electricity?

The electricity grid is a physical infrastructure that determines the configuration of the electricity market because congestion and bottlenecks shape price-areas. Increasing the shares of fluctuating energy and increasing the size of the coupled electricity markets calls for major changes in the governance arrangements supporting and shaping the electricity grids and markets. Regarding the new futures, IREMB follows the high green scenario formulated by Energinet.dk, which predicts that Denmark will have approx. 12000MW wind power by 2030. The figure below depicts 4 scenarios, depending on the degree of decarbonization and the type of market setting where electricity is priced.




Source: CE, quartz+Co, Energinet.dk, Baggrundsrapport Markedsmodel 2.0, 2015:19.

The Nordic Nordpool electricity market was in full operation in early 2000, and the amount of electricity sold on the market has increased. Currently 75% of the generated electricity is priced in the Nordpool Power exchange, while 25% is priced in so-called OTC (over-the-counter) direct sale through individually negotiated contracts. There are several possible developments for how electricity can be priced such as 1) wholesale spot markets, (2) OTC and Peer-to-Peer markets where companies like Google buy directly from producers, and (3) locally integrated energy markets at community, municipal or regional levels.

The reliance on fluctuating energy sources means that high winds will increase production and lower the market prices due to high supply. It has been shown that Denmark and neighboring countries like Germany, The Netherlands, etc. have to a large extent similar 'wind regimes', which means that these countries will have high/low wind at roughly the same time, thus, challenging the idea that excess electricity will be valuable in neighboring markets and price-areas. While open electricity markets are important for a well-functioning electricity-energy system, it is also clear that the price for electricity depends on the supply situation given the demand. But higher prices may stem from electrification driven by higher electricity demand in general, as well as on availability of high-value options for selling and pricing electricity in Power-to-Heat, or Power-to-mobility in new value chains of electrofuels based on electrolyses.

Scenario III is 'international green' which means 'ambitious green transition' combined with a reliance on pricing electricity in open electricity market platforms/price areas. These are created through many Interconnectors. This scenario presumes that electricity generated in Denmark can be sold and priced in neighboring electricity markets. Scenario IV National-green combines ambitious green transition with fewer interconnectors and is more interesting from a transition perspective, because it depicts a pricing future that allows for high-value options for selling and pricing electricity in Power-to-Heat, or Power-to-mobility in new value chains of electrofuels based on electrolyses.

Based on scenario III and IV, IREMB has formulated three different strategies for integrating fluctuating wind power to maintain peak-load capacity in the Nordpool and connected market areas, while also making it economically attractive to invest in component technologies that support the Smart Energy System transformation.

1. The first strategy '*Nordpool+Interconnectors-to-other-markets*' has Nordpool market and international markets as the primary component. The second component is the development of adjacent markets for electricification and flexibility in Denmark.
2. The second strategy '*Nordpool +DK adjacent Markets*' emphasizes the demand curve of the Nordpool market. The new adjacent national markets for electricity to heating/cooling and mobility require investments that can realize the transformation of the energy system context. With availability of Power-to-heat/cooling, heat-storage facilities, and to electrolyse systems and biogas upgrade the complementary energy system becomes technically more hospitable and economically profitable for fluctuating wind power. It is believed that higher demand for electricity will increase electricity prices in general.
3. The third strategy is the new forms of non-traditional ways of pricing electricity: e.g. *'Peer-to-Peer electricity markets'* and '*Integrative Local Energy Resource Areas*' that emphasizes using as much of the electricity resource locally within the area in which it is produced, i.e. pricing outside Nordpool. This strategy creates value by selling electricity in new value chains to heat-plants, heat-storage facilities, to upgrade biogas, or to electrolyse systems.

## IREMB combines technical scenarios with market designs to engage stakeholders

Given the mismatch situation driven by decarbonization, there is a need for politicians and regulators to step in and facilitate the development of a new market governance that combines not only a 're-design of Nordpool price-making', but also the introduction of a 'stable and high carbon price' as well as the introduction of support schemes making low-carbon investments attractive for investors and support schemes for capacity.

The novelty of the I-REMB project lies in its integrative approach that combines technical scenarios with studies of new governance arrangements for electricity market designs and for the adjacent markets for electrification that allows for greater and more flexible electricity consumption. The technical scenarios are important for providing knowledge about the potential, overall energy system efficiencies as more fluctuating energy sources are integrated in a Smart Energy System.

The 'governance arrangements' are the principles by which coalitions of actors have chosen to regulate and coordinate central activities, e.g. rules stipulating who can use the markets and regulations to incentivize economic investments and consumption practices. Hence, a key tenet of the project is that electricity markets are not 'natural' markets. Rather they result from political delegation to actors to formulate market rules and arrangements. In the case of electricity sector, the governance paradigm of this old system comprised regulation of technologies and fuels, design of electricity markets, and TSO-based rules for electricity system operation.

Electricity markets are relatively new. They have only been around for some 20-30 years even though electricity systems have been operating for 100 years. Liberalization policies and the introduction of competition from the 1990s paved the way for regulatory reforms that fostered the development of electricity markets in Scandinavia and the EU. The Danish state delegated to the Danish electricity operator (TSO) in the 1990s to join the Norwegian, Swedish and Finnish TSO's in developing a Scandinavian electricity market design (Nordpool) that ensured competitive, price-based allocation of supply-demand. With an increasing use of fluctuating energy, the technical, institutional and economic underpinnings of electricity markets needed to be addressed.

Moreover, as a governance arrangement, the Nordpool electricity market works only with the approval of the stakeholders that have 'stakes' in the working of the market: The list of stakeholders includes politicians who delegate resource allocation to the market process, those TSO's who own the market 'place', Nordpool, the scientists and experts who design and evaluate markets, and those who buy and sell electricity on the market, as well as those who use the resulting prices as incentives for further investments in capacity and transformation of the electricity and energy systems. Indeed, there are also stakeholders representing different electricity consumers such as industry and private households. In addition, the existing governance arrangements within the electricity sector include grid rules and tariffs by TSO's and Distribution System Operators (DSO's). If the heating and gas sectors are included in the energy system, this introduces governance arrangements that specify the rules for what actors in these sectors can do, calculation rules for justifying investments, rules for pricing, rules for fuel use in heat-electricity generation, and taxes and subsidies. In sum, market governance arrangements in the energy and electricity sectors represent historically embedded 'sunk costs', and current roles for incumbent actors and technologies are historically manifested in their generation and consumption practices.

IREMB identifies barriers in the current electricity market governance, which is tailored to an energy system 'of the past', and proposes designs for new electricity market governance arrangements targeting the 'future energy system'.

New 'future' market governance requires expertise-based design input, and IREMB takes a design approach. Existing electricity market designs are not naturally occurring, but highly specialized

architectural designs, which were constructed to serve the fossil fuel-based power plants of their time. Electricity markets are, just like the construction of new buildings, designed according to specific criteria with the aim of serving particular purposes. Analogous to the way safety regulations have shaped design requirements for buildings with regard to stability and safety, the design of electricity markets has always been dependent upon the physics of electricity. The TSO is the 'guardian' of a well-functioning electricity system, and this has historically resulted in a particular entanglement of electricity physics and the combination of spot and balancing markets in electricity markets.

IREMB's aim is to develop new electricity market designs that can integrate high shares of fluctuating energy sources, serve competitive allocative efficiencies for energy system operation, as well as provide necessary incentives for capacity investments and continued decarbonization in the energy system. IREMB's designerly approach is based upon the idea of intervening in existing market architectures with new design-proposals, and this calls for engaging with stakeholders in the electricity market. Based on the premise that the existing market governance has shaped identities, property rights to assets, business models of existing actors through the historical configuration of market designs, economization devices, carbon-technologies and regulations that often supports status quo, namely the 'existing governance of the past', IREMB investigates how 'governance for the future energy system' depends upon re-configurations of market governance, low-carbon technologies, economization devices (tariffs, taxes, subsidies) that must be designed in order to orientate actor identities and actions towards 'the infrastructure of the future'.

From the perspective of governance, market designs, politics and regulations are not binary opposites as often presented in public debate and politics. The interests and objectives of various stakeholders are deeply embedded in existing market designs and regulatory arrangements, and in attempts to change these. Failures can be observed in both market designs and policies, but facing the need for decarbonization, the improvements in market governance must stem from design, experiments and reflexive debates about what works.

Therefore, an important focal point for IREMB is how existing stakeholders envision the future energy system and their role in it, i.e. what are their visions and strategies, will they seek to reproduce or change their roles in the future energy system? What facilitates the role of new stakeholders associated with low-carbon technologies? In developing answers to these questions, the IREMB project will engage with multiple stakeholders to evaluate their responses to different technical energy system scenarios and proposed market designs. IREMB's approach involves a process of 'representation and intervention', indeed even provoking the stakeholders with our scenarios of the future energy system and designs for the future electricity market. The purpose is to stimulate knowledge generation, possibly to engage in mutual enactments so as to move them and us towards alternative futures.

In sum, IREMB contributes with proposals for a market governance design, a design that includes both the 'allocation of production' and the incentives for 'investments in capacity' and investments in decarbonized energy technologies'. Regarding adjacent markets, IREMB makes detailed (comparative) studies of investments in heat/cooling, mobility, storage etc. in two Danish regions (Region Sjælland and Region Midt). We study how old and new constellations of actors are involved in existing and alternative configurations of market designs, economization devices, and regulations in order to orientate micro actions towards the 'the smart infrastructure of the future energy system'. IREMB engages with energy system stakeholders to flesh out visions and strategies for the electricity market's future design and development.The market governance for a decarbonized energy system is not done 'once and for all'. The uncertainties associated with the future carbon price and the cost-performance improvements on wind, solar and storage technologies require ongoing monitoring and adjustment to the new realities.

# I-REMB Organization

ENERGINET.DK

12473 I-REMB
Innovative remaking of markets 10.000

## Core Idea

All energy technologies exist in particular market governance arrangements that shape their economics. In the energy sector there is no such thing as a natural occurring 'free market', there are only framed market arrangements such as Nordpool, the CO2-market, fossil fuel markets.

Energy System (ES) infrastructures for the 0-carbon future require 'governance that enable the shift towards the future ES'

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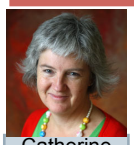
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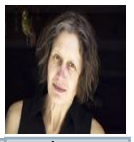
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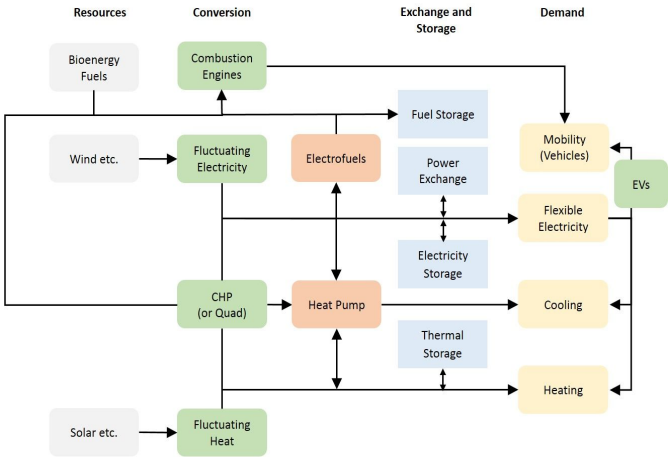
# Workpackages

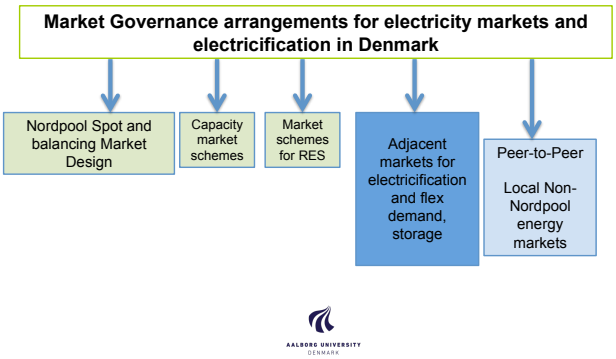



**WP 1:**
**Smart Energy System – A technical vision for a new integrated energy system**

**Simulating future load-patterns while integrating fluctuating wind power by connecting infrastructures**

IREMB Vision for an Integrated Electricity Market governance Concept

1. Nordpool electricity + Market support schemes
2. Adjacent Markets for Electricification – el-to-heat, el-to-mobility, el-to-storage (flex-demand)
3. Local non-Nordpool Peer-to-Peer Electricty markets (flex gen+demand)

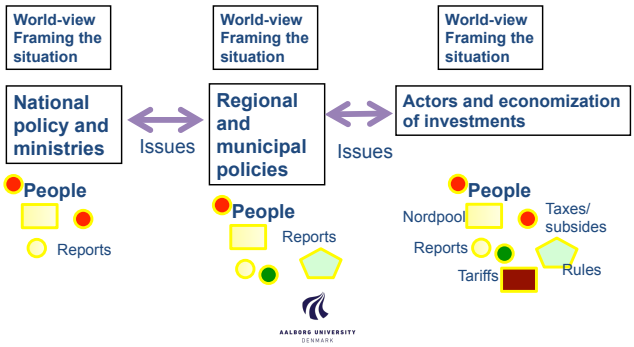



**WP2 + WP3:**
**Governance arrangements for markets and economizations**

**How can the future Nordic electricity market be designed to both allocate production and provide incentives for investments, given the Merit-Order effect of zero-marginal cost technologies?**
**How can adjacent markets for flexible electricification be**

How world-views of actors in different parts of the market governance are 'framed for investment action':

PAST AND FUTURE Market governance – and past and future ES infrastructure




**WP3+WP4:**
**The Energy system actors –**
**1) their world-views, visions for the future**
**and**
**2) how market governance shapes economization of their operations and investments**