

Final report

1.1 Project details

Project title	Innovative Re-making of Markets for a Renewable Energy System based upon wind power
Project identification (program abbrev. and file)	12473 IREMB
Name of the programme which has funded the project	ForskEl program Society and Market (Samfund og Marked)
Project managing company/institution (name and address)	Aalborg University Copenhagen, A.C. Meyers Vænge 15, 2450 København SV
Project partners	AAU, CBS, DTU
CVR (central business register)	29102384
Date for submission	December 11, 2019

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General

1.2 Short description of project objective and results

IREMB departed from concrete observations of mismatches between policy ambitions and concrete market arrangements for realizing a future low carbon energy system. Given Denmark's commitment to a 70% reduction of emissions by 2030, this mismatch may increase.

The **objective of the IREMB** project was to address this mismatch by examining how the existing energy sector market arrangements could be shifted. Market arrangements include the regulatory conditions for investments, production, and consumption of energy. Therefore, in addition to 'market prices,' rules, taxes, subsidies, and tariffs play a major role in shaping the economics of energy actors investing, producing and consuming energy.

The electricity market Nordpool is central in the transition process, but the market design suffers from the notorious 'missing money problem'. The missing money problem implies that short term marginal cost markets (also called Energy Only markets) rarely generate average prices (including scarcity prices) that can incentivize investments in power capacity. Based on idealized economic text-book thinking, these markets have proven unable to generate investments in capacity throughout Europe. The 'missing money' problem has been neglected in the Danish political debate about the role of markets in the low-carbon transition. The drastic decline in investment costs for wind and solar power has led some to emphasize 'subsidy-free wind power,' and policy makers to advocate creating 'market conditions' for all energy technology investments. However, such claims are based on a highly limited understanding of the working of the electricity market.

The IREMB project's results show: Due to the missing money problem, various forms of state backed funding may still be needed to ensure acceptable investor risks. Uncertainty regarding future prices increases investor risks, which can hinder new investments. IREMB concludes that even if the investment costs of wind and solar decline and a paradigm shift away from old fixed subsidies to ensure investments, there is still a 'case to case' need to supplement Nordpool and PPA prices with state backed investment guarantees.

Regarding the reconfiguring of market arrangements within heating to enable cross-sectoral, deep decarbonization, our study shows that heat-providers are willing to invest in low carbon solutions. IREMB also shows that the regulatory classification of biomass as CO₂ neutral, and the policies exempting biomass from energy taxes and subsidizing the shift from coal to biomass-power plants have since the 1990s led to a technical, economic and political lock-in of biomass in combined heat and power. Denmark's high import of biomass is unsustainable, because biomass is not imported from countries who have signed the Paris Agreement. The classification of biomass as carbon-neutral is highly disputed. Findings from carbon cycle science suggest that under certain conditions, burning biomass has the same or higher CO₂

emissions than coal. It is important to develop pathways ways out of the biomass dependency.

With cheap biomass dominating heat production and a high tax on electricity, this has dis-favored investments in heat-pumps and, thereby, heat sector electrification. Furthermore, IREMB shows how mandatory calculation rules prevents low-carbon investments in the heating sector. The rules for calculating the ‘societal value of investment options’, specified by the Ministry of Finance, are not constructed to reflect and support low carbon transition pathways in the heating sector. First, future prices derived from high-carbon-emission scenarios for the future development of the energy system, maintains status quo and are at odds with the Denmark’s commitment to the Paris Accord. Second, dis-utilities related to fuel production located outside Danish boundary are systematically ignored in the socio-economic prices. Third, carbon emissions are considered a policy cost, and the chosen calculation methods provide relatively low estimates of these policy costs. Therefore, existing market arrangements and mandatory calculation rules prevents new, flexible electricity demand from heating from becoming actionable for actors.

Regarding the design of new market arrangements for increased system flexibility, experiences from EcoGrid Bornholm demonstrated that the construction of price sensitive consumers that would provide some of the needed flexibility was difficult to realize; both as a direct user-experience and as part of an aggregator-business model.

The slow decarbonization of the heating sector and creation of flexible demand, may reflect a lack of policy commitment to Smart Energy systems thinking with strong cross-sectoral connections. For decades the ‘interconnector paradigm’ for trading and flexibility has been useful. IREMB has examined the methodology behind business cases for interconnectors, and shows that both the grid-tariffs and calculative economic methods used to calculate the business case for interconnectors systematically favor international trade of electricity. Thus, the ‘interconnector paradigm’ informing policy is inadequate, and the calculative methodologies must be reconsidered in order to find the most cost-efficient path towards 100 percent renewable energy systems.

A key challenge in transitioning to a low carbon economy is the decarbonization of transport. Although electrification is widely accepted as the strategy for decarbonizing light vehicles and trains, electrification of heavy-duty road transport, shipping and aviation is very difficult. Different fuels are needed for different purposes and in different scales. Deep decarbonization will not be possible without large volumes of low carbon fuels. Denmark is in a unique position. There are companies along the potential new value chain – within wind power, electrolysis, ship engines, and ship owners – interested in the development of low carbon fuels, electrofuels. The promise of electrofuels, however, depends upon the Danish government’s ability to integrate climate, energy and industrial policies – to a much greater extent than hitherto. State money is needed in ‘risk sharing models’ that can reduce investor risk in industry, similar to how investor risk was reduced for wind power investors.

IREMB projektets udgangspunkt har været konkrete observationer af uoverensstemmelserne mellem politiske ambitioner og de konkrete markedsarrangementer for at realisere et CO₂-frit energisystem. I betragtning af Danmarks forpligtelse til en 70% reduktion af drivhusgasudledningerne i 2030 er uoverensstemmelserne vokset. Formålet med IREMB-projektet har været at undersøge, hvordan de eksisterende markedsarrangementer for energisektoren kan re-designes med henblik på at sikre en omstilling af energisektoren. Markedsarrangementer omfatter de lovgivningsmæssige rammer for investeringer, produktion og energiforbrug, fx regler, skatter, subsidier og tariffer, som påvirker energisektorens aktørers handlingsmuligheder.

Elmarkedet, Nordpool, spiller en afgørende rolle for energisektorens omstilling, men markedsdesignet svækkes afgørende af "the missing money problem," der indebærer, at markeder baseret på marginale omkostninger (også kaldet Energy Only-markeder) kun sjældent genererer gennemsnitspriser (inklusive 'scarcity prices'), der giver tilstrækkelig incitament til investeringer i kapacitet. Baseret på idealiseret økonomisk lærebogstænkning, har disse markeder vist sig ude af stand til at generere investeringer i kapacitet i hele Europa. Problemet med "the missing money" er blevet overset i den danske politiske debat om den grønne omstilling. Det drastiske fald i investeringsomkostningerne for vind- og solenergi har ført til at disse energikilder nu betragtes som nærmest 'subsidiefri', og til at politiske beslutningstagere ønsker at skabe 'markedsvilkår' for alle energiteknologiske investeringer. Sådanne forestillinger er imidlertid baseret på en meget begrænset forståelse af el-markedets design og funktion. Resultaterne fra IREMB-projektet viser: På grund af "the missing money problem" kan der stadig være behov for forskellige former for statsstøttet finansiering for at sikre acceptabel investorrisiko. Usikkerhed omkring fremtidige priser øger investorrisikoen, hvilket kan forhindre de nødvendige investeringer. IREMB konkluderer, at selv hvis investeringsomkostningerne ved vind- og sol falder, og subsidierne bortfalder, vil der fortsat være behov for at supplere Nordpool- og PPA-priserne med statsstøttede investeringsgarantier.

I forhold til en grøn omstilling i varmesektoren, viser vores undersøgelse, at varmesektorens aktører er villige til at investere i løsninger der kan fremme den grønne omstilling. IREMB viser også, at den lovgivningsmæssige klassificering af biomasse som CO₂-neutral samt de politikker, der fritager biomasse fra energiafgifter og subsidierer overgangen fra kul til biomasse-kraftværker siden 1990'erne, har ført til en teknisk, økonomisk og politisk "lock-in" af biomasse i kraftvarmesektoren. Danmarks høje import af biomasse er uholdbar, fordi biomassen ikke importeres fra lande, der har underskrevet Parisaftalen. Klassificeringen af biomasse som kulstofneutral problematiseres i stigende omfang. Resultater vedrørende kulstofcyklussen antyder, at forbrænding af biomasse under visse betingelser har de samme eller højere CO₂-emissioner end kul. Det er således vigtigt at begrænse biomasseafhængigheden.

Kombinationen af billig biomasse, der dominerer indenfor varmeproduktionen, og en høj skat på elektricitet, har begrænset investeringer i varmepumper og dermed elektrificeringen af varmesektoren. Derudover viser IREMB, hvordan obligatoriske regnemodeller forhindrer grønne (low carbon) investeringer i varmesektoren. Reglerne for de samfundsøkonomiske beregninger, der er specificeret af Finansministeriet, er ikke konstrueret til at afspejle og understøtte en grøn omstilling. Det er der flere grunde til. For det første er de fremtidige priser baseret scenarier med høje CO₂ udledninger, hvilket

fastholder status-quo og er i uoverensstemmelse med Danmarks tilslutning til Paris-aftalen. For det andet ignoreres de problemer/omkostninger, der forbundet med brændstofproduktion udenfor Danmarks grænser, i de socioøkonomiske priser. For det tredje betragtes CO₂-udledninger som en politikomkostning, og estimerne heraf er forholdsvis lave i valgte beregningsmetoder. De eksisterende markedsarrangementer og obligatoriske beregningsregler forhindre, at aktørerne kan udvikle nye, fleksible former for efterspørgsel på el.

Med hensyn til udformning af nye markedsarrangementer, der kan sikre den nødvendige systemfleksibilitet, viste erfaringer fra EcoGrid Bornholm, at konstruktionen af prisfølsomme forbrugere, der ville levere noget af den nødvendige fleksibilitet, var vanskelig at realisere; både som en direkte brugeroplevelse og som en del af en aggregator-forretningsmodel.

Den langsomme omstilling af varmesektoren og skabelsen af fleksibel efterspørgsel kan afspejle en mangel på politisk engagement i at udvikle Smart Energy-Systems, baseret på en stærk sektorintegration. I årtier har 'interconnector-paradigmet' for el-handel og fleksibilitet været nyttigt. IREMB har undersøgt metodikken bag forretningsmodelberegningerne for interconnectors og viser, at både net-tarifferne og de anvendte økonomiske beregningsmetoder systematisk favoriserer international handel med elektricitet. "Interconnector-paradigmet," som informere policy, er således utilstrækkelig og beregningsmetoderne skal genovervejes for at finde den mest omkostningseffektive vej mod 100 procent vedvarende energisystemer.

En af nøgleudfordringerne i omstillingen til et CO₂-frit samfund er de-carbonisering af transport. Selvom elektrificering er bredt accepteret som strategien for lette køretøjer og tog, er elektrificering af den tunge vejtransport, skibsfart og luftfart meget vanskelig. Forskellige brændstoffer er nødvendige til forskellige formål og i forskellige skalaer. Dyb de-carbonisering vil ikke være mulig uden store mængder brændstof med et lavt kulstofindhold. Danmark er i en unik position; med virksomheder – inden for vindkraft, elektrolyse, skibsmotorer og skibsfart – der er interesseret i udviklingen af nye brændstoffer med lavt kulstofindhold, de såkaldte "electrofuels". Der er et potentiale for helt nye værdikæder. Hvorvidt disse muligheder kan realiseres vil afhænge af den danske regerings evne til at integrere klima-, energi- og industripolitikker - i langt større grad end hidtil. Endvidere vil statsstøtte være nødvendigt i udviklingen af 'risikodelingsmodeller', der kan reducere investorriskoen for industrien, svarende til hvordan investorriskoen blev reduceret for investorerne i vindkraft.

1.3 Executive summary

The decarbonization of energy systems is likely to be one of the most complex design- and governance challenges of the 21st century. In the preceding decades, many efforts have been invested in addressing this challenge from a technical perspective. Although feasible technical pathways for decarbonization are well described in engineering models, the specification and 'model-visibility' of such technical pathways is far from the only ingredient needed for de-carbonization to happen. Moreover, the concrete market arrangements where actors on the ground undertake in-

vestments and consumptions that make or break low carbon transitions are understudied.

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The **objective of the IREMB** project was to address this mismatch by examining how the existing energy sector market arrangements could be shifted. Market arrangements include the regulatory conditions for investments, production, and consumption of energy. Therefore, in addition to 'market prices,' rules, taxes, subsidies, and tariffs play a major role in shaping the economics of energy actors decisions in investing, producing and consuming energy.

The electricity market Nordpool is central in the transition process, but the market design suffers from the notorious 'missing money problem'. The missing money problem implies that short term marginal cost markets (also called Energy Only markets) rarely generate average prices (including scarcity prices) that can incentivize investments in power capacity. Based on idealized economic text-book thinking, these markets have proven unable to generate investments in capacity throughout Europe. The 'missing money' problem has been neglected in the Danish political debate about the role of markets in the low-carbon transition. The drastic decline in investment costs for wind and solar power has led some to emphasize 'subsidy-free wind power,' and policy makers to advocate creating 'market conditions' for all energy technology investments. However, such claims are based on a highly limited understanding of the working of the electricity market.

The IREMB project's results show: Due to the missing money problem, various forms of state backed funding may still be needed to ensure acceptable investor risks. Uncertainty regarding future prices increases investor risks, which can hinder new investments. IREMB concludes that even if the investment costs of wind and solar decline and a paradigm shift away from old fixed subsidies to ensure investments, there is still a 'case to case' need to supplement Nordpool and PPA prices with state backed investment guarantees.

Regarding the reconfiguring market arrangements within heating to enable cross-sectoral, deep decarbonization, our study shows that heat-providers are willing to invest in low carbon solutions. IREMB also shows that the regulatory classification of biomass as CO₂ neutral, and the policies exempting biomass from energy taxes and subsidizing the shift from coal to biomass-power plants have since the 1990s led to a technical, economic and political lock-in of biomass in combined heat and power. Denmark's high import of biomass is unsustainable, because biomass is not imported from countries who have signed the Paris Agreement. The classification of biomass as carbon-neutral is highly disputed. Findings from carbon cycle science suggest that under certain conditions, burning biomass has the same or higher CO₂ emissions than coal. It is important to develop pathways ways out of the biomass dependency.

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investment options’, specified by the Ministry of Finance, are not constructed to reflect and support low carbon transition pathways in the heating sector. First, future prices derived from high-carbon-emission scenarios for the future development of the energy system, maintains status quo and are at odds with the Denmark’s commitment to the Paris Accord. Second, dis-utilities related to fuel production located outside Danish boundary are systematically ignored in the socio-economic prices. Third, carbon emissions are considered a policy cost, and the chosen calculation methods provide relatively low estimates of these policy costs. Therefore, existing market arrangements and mandatory calculation rules prevents new, flexible electricity demand from heating from becoming actionable for actors.

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1.4 Project objectives

IREMB departed in concrete observations on mismatches between policy ambitions and concrete market arrangements when it comes to realize a future low carbon energy system. Especially the ‘missing money’ problems inherent in the marginal cost electricity market design, Nordpool.

The objective was to analyze the consequences for Nordpool pricing when the share of zero-marginal cost technologies like wind power increases, and to see if the new electricity demand from PtX in heating and electrofuels could compensate and increase the prices.

The project followed the milestones for WP1.

In order to make the analysis of the consequences, WP1 made a technical Smart Energy System scenario of the low carbon energy system with high shares of wind power and new PtX-demand was linked to the Nordpool pricing model. Analysis of duration curves of different power producers showed that new demands could increase the price, but not solve the missing money problem.

On this basis WP2 worked with the possibilities to redesign of the Nordpool and Power Purchase Agreements to overcome the missing money problems. The conclusion is that investors still need state-backing to reduce their risks.

WP2 had several problems to follow the milestones because of staffing issues: Central staff left academia, and the specialized competencies were not easy to replace. This happened in fall 2017 and again in 2018. That delayed WP2, and also reduced their ability to include work on the EU electricity market guidelines with Nordpool. For these reasons the project ending was extended from May 2019 to October 2019.

WP3 was also delayed in Milestones regarding the first mapping of heating utilities strategies for decarbonization, but caught up in later phase. WP3 focused ‘on the ground’ investment practices in the heating sector, and found that the existing market arrangements and mandatory calculation rules are favoring biomass instead of heatpumps.

WP4 focused on workshops and engagement with actors, and carried out three workshops with actors from the energy field. The first (June 2017) was a debate on the ‘Energikommissionens’ proposal for the future electricity market. The second, in March 2019 on the future of electrofuels was hosted by Siemens-Gamesa, and had participants from potential Danish actors in this new value chain. Finally, in September 2019, another workshop, hosted by the Danish Windpower, on the promises on PPA’s as a solution to the missing money problem was held with stakeholders to discuss WP2’s model.

Due to the delay in WP2 the specific inputs for re-design of electricity markets, the two last workshops were delayed, and it was limited time to develop more precise and concrete risk sharing models with real world investors.

1.5 Project results and dissemination of results

The collaborative work in the 4 WP’s has worked well, but we had some delays due to staffing issues in WP2: Central staff left academia, and the specialized competencies were not easy to replace. This happened in fall 2017 and again in 2018. That delayed WP2, and also reduced their ability to include work on the EU electricity market guidelines with Nordpool. This was a challenge as the concrete work on electricity markets re-design, and discussion of whether state subsidies could be avoided in the future was important.

The IREMB project has provided important answer to this main challenge, but we could have had only limited time to develop more precise and concrete risk sharing models with real world investors.

Regarding the challenges to electrify the heating sector we did provide results that confirmed the existing studies of problems in existing rules, taxes and tariffs. But IREMB also pointed to the central role of mandatory calculative rules set by the Ministry of Finance, that systematically prevent decarbonization of heating, and favors investments in interconnectors.

The results have been disseminated in published papers in journals, at several international conference presentations, and at IREMB's own international conference in Denmark, October 2019.

1.6 Utilization of project results

As a social science project the questions raised in this section are not relevant for IREMB.

1.7 Project conclusion and perspective

The results from the project points clearly to a more active role of the state in directing and facilitating the urgent deep decarbonization transition to a low carbon energy system that IPCC is advocating.

The cocktail of low investment cost of wind and solar power, a few 'subsidy-free' bids, and the economic doctrine of 'more markets' have led politicians and stakeholders to have high expectations to the central role of the electricity market in particular and the role of 'markets in energy sector in general' in the transition process. However, the results from the IREMB project points out that because of the specificity of the electricity market and other energy sector market arrangements in heating-cooling and transportation, it is not a simple thing to 'make the markets work and incentivize the low-carbon appropriate decisions in investing, producing and consuming energy.

- There is no such thing as a 'free and natural market' that exists without specific rules, so when the climate council chairman and politicians are calling upon 'markets in the energy sectors' to set prices, they must be specific about what they mean about the existing market arrangements because they include the regulatory conditions for investments, production, and consumption of energy. Therefore, in addition to 'market prices,' rules, taxes, subsidies, and tariffs play a critical role in incentivizing and shaping the economics of the decisions of all actors who invest, produce and consume in relation to the energy system.
- While wind power and solar power can claim to be 'cheapest' investment option, and be free of old type full subsidies. The missing money problem is a chronic design problem and will remain in the Nordpool electricity market and there is a continued need for massive wind power investments towards 2030. That means that the state must re-think the use of state-backed funding and be involved in developing new 'risk sharing models'.
- The state must be active in re-designing the existing market arrangements of rules, taxes, tariffs, and tax-exemption that maintains biomass dominated heat production, and prevent electrification with collective heat pumps etc.
- The state must be active in re-designing the mandatory calculation rules set by the Ministry of Finance to 'qualify' heat investments, as existing calculation rules systematically delays decarbonization in heating.
- The calculation rules include a too low CO₂ price, that systematically favors fossil fuels. The Danish calculation rules (samfundsøkonomiske beregninger) must reflect the IPCC urgency, and not accepting the too low carbon prices from the EU-carbon market.
- The state must be active and prepared in 'risk sharing' in the new electrofuel value chain to secure the necessary capital investments and reducing pro-

duction costs. Patient money and venture capital is not readily available in Denmark. Developing electro fuels and bringing them to market is capital intensive, particularly due to the high fixed costs of electrolysis. But given the active interest and competences of major Danish companies the new electrofuel value chains may become a new wind turbine industry.

Thus, the overall conclusion from the IREMB project is to re-think and re-introduce the active role of state regulation in market arrangements in order to make deep decarbonization happen in the energy system.

But it is also important that politicians do not 'fumble the start of the future for a low carbon energy system' in the same way as the unclear and shifting policies has fumbled the start of the future for electrical despite the readiness of business actors.

It is important not to see it as a simple question of 'more markets' or a 'either market or policy' which dominates the debate, but of their combination. There is already state regulation (and vested interests as in biomass) involved in maintaining markets arrangements for existing fossil fuels, and therefore it is both politically appropriate and necessary to re-design existing market arrangements to facilitate investments and consumption of low carbon technologies.

Annex

Add links to relevant documents, publications, home pages etc.

Home page iremb.org

Publication list to be completed