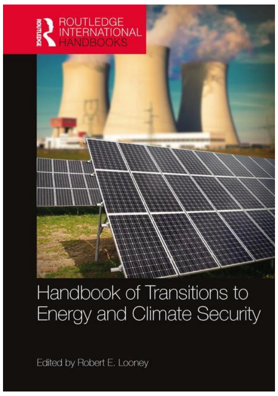

Handbook of Transitions to Energy and Climate Security

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Struggles in Denmark's transition towards a low carbon future

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Struggles in Denmark's transition towards a low carbon future

Shifts in the energy technology assemblage

Peter Karnøe and Jens Stissing Jensen

Introduction[1]

In 2015, Denmark set a world record when wind power generated 42.1% of the nation's total electricity.[2] For 16% of the time, wind power alone generated more than 100% of the electricity demand in western Denmark, and excess electricity could be sold and transmitted to neighbouring countries like Norway, Germany and Sweden. This high level of wind power penetration has enabled the country to shift away from the use of fossil fuel-based power plants to generate electricity, and is the main reason that Denmark is the top-ranked country based on the Climate Change Performance Index created by Climate Action Network Europe and Germanwatch for 2015.[3] The ranking is based on factors such as overall development of a CO_2 emissions strategy, electricity generation from renewable sources, energy efficiency, and an ambitious and consistent climate policy. The recent ranking was based on 2013 statistics, which reflected the cumulative effects of past policies driven by social democratic governments, sometimes with pressure from left wing and green parties. The assessment also highlighted Denmark's 2012 Energy Agreement, which cemented a broad political compromise for reducing CO_2 emissions through energy efficiency by combining electricity and heat generation and making wind power the core energy technology in the future low carbon energy system.

However, with the election of a new centre-right minority government in June 2015, the ambitions of Denmark's previous climate policies were not to be realized. This government has introduced the notion of 'green realism' into its climate policy, aimed at tempering the transition process towards a fossil-free society by 2050, similar to the centre-right government of 2001–2008 that almost brought climate policies to a full stop. Green realism is based on the argument that given its top rank worldwide, Denmark can relax its policies and reduce its ambitions due to the material and economic costs of integrating increasing amounts of wind-generated electricity into the electricity/energy system.

The policy change was noticed immediately, and at the Conference of Parties (COP 21) in Paris in December 2015, Denmark was given the distinct 'honour' of receiving the 'fossil-of-the-day' award, which is given to the country that has abandoned former climate policies with no broader concerns for the greater good. This distinction was bestowed by the Climate Action Network, which earlier that year had ranked Denmark highest based on its Climate Change Performance Index mentioned earlier. The fossil-of-the-day award may be a surprise to many outsiders, but it is a reminder that societal transitions cannot be reduced to technological innovation alone. Whenever a centre-right government has come into power in Denmark, climate policies have been almost completely thwarted. However, the context for stopping or relaxing climate policies in 2015 is very different from 2001, given increasing momentum of the transition to a low carbon energy system outside Parliament.

First, the large-scale penetration of wind power (42.1% in 2015, up from 10% in 2001) represents a new material reality. Wind-generated electricity thus functions as a 'living material thing' that threatens to destabilize the frequency in the Danish electricity grid, which must be balanced at 50 Hz at all times to prevent blackouts. Furthermore, the market design of the Nordic electricity market appears to be incapable of generating prices that provide adequate financial incentives for 'system electricity services' (e.g., different plant types and load services associated with spot balancing load capacity). Current prices are too low, and as a consequence, 35% of central power plant capacity was shut down between 2008 and 2013. In this way, high wind power penetration represents a new reality that has disrupted the intertwined material, regulatory, organizational and market arrangements that served the fossil based electricity system quite well.[4] The increasing amount of wind-generated electricity is thus turning into a fundamental systemic problem for the energy system as a whole.

Second, while the centre-right minority government advocates green realism, many actors in the energy system and its suppliers already act on the basis of a new world view focused exclusively on making a full transition to an energy system based on wind power. Green realism thus faces opposition not only from NGOs, but increasingly from established organizations in the energy and industrial sectors, and prominent CEOs from new green, low carbon, clean-tech companies. While the priorities of the right wing minority government are fairly predictable, it is somewhat surprising to witness this outspoken resistance to the green realism policy from many organizations, industries, municipalities and experts. Indeed, the Danish energy and climate policies have created new business opportunities and new industrial clusters and strongholds for wind power, district heating, and energy efficiency-related goods and services, which have given rise to shifting interests.

Indeed, this kaleidoscopic picture of the current diverse shifts in the Danish transition to a low carbon energy system reveals conflicting political positions[5] yet, at the same time there is a strengthening of new material and discursive realities that constitute a new normal. As such, climate policy must address not only the systemic problems of wind power integration, but also the new business opportunities and industrial transformations associated with investing in the goods and services that will comprise the future low carbon energy system. In this chapter, we describe the surprising outcome when green realism meets the new climate policy normal, in which both material problems and industrial cluster business opportunities must be considered. We use the concept of sociotechnical assemblage to understand the conflict between political-ideological realities and the effects of increasing momentum and material and structural demands for continued change, as the concept allows for the co-existence of differentiated ambitions and fragmentation while maintaining momentum.

Shifting sociotechnical assemblages in the energy system transition

A salient concern in many contemporary climate policies is how to de-carbonize large-scale societal systems in domains such as water, energy, transportation and food. While technological components and infrastructures constitute a large part of such systems, empirical analyses in the tradition of science, technology and society studies (STS) stress that transitioning from high carbon to low carbon energy systems cannot be reduced to managing technical dimensions.[6] From an STS perspective, there is no such thing as pure technology[7] just as there is no such thing as a 'natural and pure market'.[8] Scholars in this tradition typically perceive societal systems as 'seamless webs' in order to underscore how such systems only become 'real' through multiple relations and reciprocities among people, politics, regulation, technical design and production, science and the economic market.[9]

Specifically, we draw on the STS-inspired concept of socio-technical assemblages in order to tell the story of the transition of the Danish energy system. This concept is particularly well-suited to understanding both *persistence and change* as phenomena that are endogenous to the established structures, building blocks and processes of societal systems. The assemblage concept presents a relational way to understand 'systems', and is a new way of examining the part-whole connection without resorting to analysing completely ordered wholes using one script or translator, as is the presumption in systems theories.[10] Instead, assemblages consist of networked actors made from combinations of various intermediaries such as technical, scientific and legal texts, imaginaries and narratives, artefacts, money, skills and competences as well as criteria used to justify and legitimize actions.[11]

Importantly, however, a socio-technical assemblage is not a fixed entity, but an 'open building site under constant construction' comprised of groupings of heterogeneous actors and intermediaries that shape and define each other's technologies, cognitions, interests and identities.[12] This mutual shaping may create enough convergence to generate momentum[13] that harnesses the inputs of distributed actors.[14] For example, the fossil fuel-based centralized electricity system is an example of an assemblage that grew from nothing in the 1880s to complete dominance in the 1980s through translation of the heterogeneous elements that were shaped and connected to constitute the emergent 'system', and thereby make coordinated actions possible.[15] Although the centralized fossil fuel-based electricity system may appear to be relatively fixed, it is comprised of stabilized relations between many elements that may be challenged and reorganized. Since the 1980s, the particular relations of this configuration have been increasingly challenged by concerns over material effects on the environment and climate that eventually were addressed in COP meetings in strategic battles of transition between resistant 'incumbents' and 'challengers'.[16] While such declarations are important, COP21 also illustrates that systems should not be mistaken for homogenous wholes. The groupings of 'parts' (such as nations, citizens' groups, corporations, municipalities or 'municipalities for climate change') comprise particular and often precarious networked constellations of contextually-situated action points. The degree of convergence, stability and sharedness that characterizes such a constellation is an empirical matter.

Despite the possibility of convergence, the assemblage perspective differs from more static and structural views of societal systems (e.g., system concepts such as socio-technical regimes or techno-institutional complexes). Static concepts tend to represent systems as if there is a common overarching whole that 'acts' on all involved actors homogenously. Static-structural approaches thus filter away the heterogeneity of situated practices and 'frames of reference' of those involved in a societal system. This makes it analytically difficult to accommodate both developmental stability and the potentially transformative dynamics of agents as they engage in new concerns, struggles and negotiations about 'next steps'.

Unlike the static structural views of societal systems, the concept of socio-technical assemblage embraces the incompleteness, multiplicity and precariousness of the composite relations that make up so-called systemic wholes or totalities. Whatever coherence and convergence exists is constituted by the *situated actions* of the participating actors, who ascribe sense and meaning to their actions based on particular situated framings of their entanglement.[17] A situated entanglement is associated with particular frames of reference, which are rooted in concrete social and material practices in such domains as design and production, science and research, politics and regulation, media, NGOs, markets and users.

Since a socio-technical assemblage is an 'open building site under constant construction' comprised of groupings of heterogeneous actors and intermediaries that shape and define each other, it is also important to make an analytical distinction between an assemblage and the different networked agencies that comprise it. Depending on the state of the assemblage (i.e., the degree of convergence, stability and sharedness) these agencies may have different and competing agendas or interests, and consequently may want to take the unfolding of the assemblage in different directions. Networked agencies are integral to assemblages, but may actually compete with each other.

A methodological strategy by which to embrace both the static nature of a structure and the processual dynamics of a societal system is to apply the notion of socio-technical assemblage both in a 'noun version' and in a 'verb version' as suggested by Law: 'If "assemblage" is to do the work [of replacing views of systems] that is needed then it needs to be understood as a tentative and hesitant unfolding, that is at most very partially under any form of deliberate control. It needs to be understood as a verb as well as a noun.'[18]

The 'verb perspective' considers how associations recursively unfold in localized processes by which networked agencies typically manoeuvre, which are neither static nor given, but constantly in-the-making and re-making. We argue that this relational understanding of a 'system' is particularly sensitive to the co-existence of multiple agencies. Agencies are networked constellations of regulations, resources and calculation located within the broader assemblage that provides actors with locally-situated 'frames' for how to make sense of their concrete socio-material engagements in the operation, reproduction or transformation of the energy system. Even from the verb perspective, assemblage activities may nevertheless stabilize, as did the networked agencies associated with the centralized electricity system, and become somewhat predictable as they become increasingly irreversible and gain momentum.

The 'noun perspective' shifts attention to how relations among the socio-technical elements of the assemblage have stabilized and make up a relatively fixed structure (i.e., Callon's 'Techno-economic Networks and Irreversibility'). From the noun perspective, it is possible to make partial summaries (representations) of the state of an assemblage in terms of its politics, policy plans, and scientific and technological accomplishments (e.g., 42.1% wind power penetration), current public sentiment, or the effectiveness of current market arrangements. Various reports and rankings are examples of such summaries of the state of an assemblage; however, the particular 'reality made visible' from these reports depends on the context of the observer and the concepts, categories, etc. used to make the measurement.[19]

In this chapter, we draw on both the verb and noun perspectives in describing the Danish transition away from fossil fuels by following some elements and agencies involved in shifting the assemblage. From a processual view, transitions are not the result of outside structures 'acting upon' existing actors. Assemblages shift as locally-situated networked agencies in the domains of politics and regulation, design and production, science and technology research, markets and users, and media and public debate take new actions and attempt to interest, provoke or coercively force other actors to re-frame themselves and their actions and contribute to shifting the socio-technical assemblage through recursive processes.[20] Any networked agency needs legitimate referents for maintaining or shifting action, and materially, these may be highly diverse. The reference points may include demonstrations that provoke new policy actions, watershed events like the Fukushima accident, the gradual acceptance of IPCC climate science as a reference point for new actions, or new discursive (i.e., the ideological doctrine of 'free markets') and calculative standards and valuation frames used to justify investment decisions in companies or national policy actions. The shifting of assemblages is not like linear rational policymaking, with clear steps for getting from A to B; nor is it guaranteed to be successful, as such shifts happen through distributed agencies, struggles, skills and negotiations that temporarily mobilize and enrol new allies. We use the concept of socio-technical assemblage to follow the 40-year transition of the Danish energy system, and show how it has been modulated in a series of contradicting and piecemeal movements whereby actors have struggled to develop and promote new framings of the energy system that ascribe new roles to individual components.

Towards a model of shifting technologies and practices in the energy assemblage, 1976–2001

In 1973, before the first energy crisis, Denmark had created a highly reliable energy supply to provide both electricity and heating to homes, industry and the public sector. The availability of light and the so-called '21-degree' cultural standard were now defining the new normal of comfort in modern society.[21] These services were provided by an energy assemblage of centralized electricity and heat comprised of oil boilers, district heating systems, and co-generation. Fuel-wise, this assemblage produced about 95% of its energy by burning cheap and abundant oil, which had replaced city gas, coal and coke. The biggest challenge seemed to be when to add nuclear power to the energy assemblage built around the centralized electricity system. A strong coalition of major groups from the political, science, industrial and electricity domains were behind nuclear power as the next natural step.

Denmark's oil dependency was revealed during the 1973 oil crisis. When Arab oil producers enacted an embargo on Denmark (after it became known that the prime minister supported Israel during a closed meeting), the price of oil quadrupled overnight.[22] Denmark had taken great pride in its energy assemblage that provided a reliable supply of centralized generation of electricity and heat; yet, it had no contingency energy policy.

The first political response was to create a series of energy policy reports on possible energy futures and provide some techno-economic calculations so as to compare various scenarios. Policy priorities outlined in the first Energy Plan created in 1976 were:

1 reduce oil dependency and improve energy supply security (coal and nuclear power);
2 build a multi-directional energy supply that included domestic Danish energy sources;
3 promote energy savings and energy efficiency; and
4 establish a national heat plan that prioritized how to heat buildings most effectively in different districts.

This framing of the official energy policy did not go uncontested, however. A new agency network comprised of NGOs, scientists and civil society actors published the so-called Alternative Energy Plan (AE'76). It suggested a policy based on energy efficiency by advocating more co-generation of power and heat, and envisioned that wind power parks could contribute 12% of domestic electricity production by 1995. The AE'76 was a central calculative device with different calculations and scenarios for energy growth, and contributed to an alternative socio-technical vision that helped to broaden the situated and public mind-set of what could be a possible future energy system.[23] The role of wind power was, however, regarded as 'white noise' or 'meaningless words/sounds' (similar to reactions when the electronic synthesizer was introduced)[24] in relation to the dominant and normalized framing of the future energy system. For example, the Danish Electricity Association (DEA) ridiculed the idea of using wind power from the very beginning in the 1970s.[25] In a brochure, the DEA claimed that the electricity generated from wind power would not be sufficient to heat the waterbeds in which the (hippie) windmill owners were sleeping.[26] However, this renewable energy network continued to shape the public debate by advocating and demonstrating alternative futures by offering reports such as the Alternative Energy Plan of 1983, which criticized the official Energy Plan of 1981. Their texts materialized alternative visions of a renewable energy system based on wind power, that deviated completely from the official energy plans and DEA's nuclear future, and were, by the majority of actors, seen as 'white noise' and not immediately incorporated into the official and dominant energy policy discourse.

The official 1976 and 1981 Energy Plans did, however, form the basis for two relatively separate policy approaches that shifted agencies in the energy technology assemblage. The main approach consisted of a reorganization of the established energy system involving three major changes. First, power plants were converted from oil to coal and natural gas. Second, in order to build domestic energy capacity, a piped heating infrastructure for district heating and natural gas was constructed in the Danish part of the North Sea with the intent of fulfilling the heat demands of more than 50% of all dwellings. Third, to save energy, new (and later upgraded) insulation standards were incorporated into building regulations, and taxes on fossil fuels were raised to incentivize energy efficiency in industry.

These initiatives triggered new agencies to act and collaborate. For example, district heating infrastructures were developed by municipalities in collaboration with user-owned local district heating plants. Further, municipal gas companies were added to this infrastructure along with incineration plants that produced heat from waste. Energy taxes were structured to generate economic incentives to act in accordance with policy goals and regulations. During the 1990s, a more fundamental reorganization took place as many centralized power plants were replaced by hundreds of private, decentralized production units located closer to consumers with heat demands. New formalized agencies with new competencies, roles and interests were being developed in the energy technology assemblage.

These policies of the 1980s and 1990s were highly successful, and energy consumption stabilized around 800 PJ despite a doubling of national economic output from 1985 to 2010. In addition, the energy tax was generating about €7 billion annually for the state budget by 2013. While this was good for state finances, it also made shifting assemblages difficult because replacement of tax revenues would come at the expense of private actors.

Relatively isolated from this large-scale reconfiguration of the oil-dependent energy technology assemblage, the development of wind turbines took off in the early 1970s. Grassroots organizations and entrepreneurs engaged in early experimentation independent from the national electricity grid, while others focused directly on developing grid-connected wind power and set in motion shifting assemblages related to regulations for the ownership and connection of wind turbines to the grid[27] (multiple accounts from grassroots found in Beuse et al., 2000). These efforts were complemented by the development of a research programme and policy approval of economic subsidies for wind turbines. There was, however, no a priori functional plan for these subsidies; rather, wind power policy was assembled as a new policy object in a 'garbage can-type non-linear process'.[28] The convergence was, however, weak and precarious as critics and sceptics strongly contested wind power in order to influence adaptive expectations about its role in the electricity system.

For instance, one debate in the early 1980s centred on the size of 22–30–55 kW wind turbines, deemed 'too small to matter energy production wise', compared to the large-scale wind power programme based on 600 kW wind turbines. However, during the mid-1980s, the wind power network was strengthened by a surprising set of relations to new issues: export income and jobs in Denmark. Exports of small (55–75 kW) Danish wind turbines increased from 30 to 2,000 per annum between 1982 and 1985, making the wind turbine more popular and legitimate in Denmark.[29] The booming export market had a positive effect on the domestic market, as it shaped new expectations, through which wind power policies were increasingly justified by reference to the effects on employment and export benefits. This happened at a point in time when the existence of wind power in Denmark was fragile and contested for being subsidized, expensive and irrelevant to base-load electricity production. As part of the 1985 Energy Act, energy authorities made an agreement with the electric utilities that they would install 100 MW of wind power energy between 1986 and 1990, on the condition that private installations would be restricted. This represented a substantial increase in the home market, as private installations from 1978 to 1985 totalled only 75 MW. Wind power's share of Danish electricity generation only amounted to 2% by 1990, however, and the material presence of wind power in the grid was not problematic.

By the year 2000, the energy assemblage thus consisted of an energy system organized around piped heating infrastructures (natural gas and district heating infrastructures) and a high level of co-generation of heat and power. Relatively separated from this, the wind power assemblage was materially gaining momentum, accounting for about 10% of electricity generation. In the following three sections, we outline the recent transition processes of the Danish energy system by analysing how these two energy technology assemblages were increasingly interweaved after 2000. The story focuses on how the shifting of agencies created various material effects as wind power and other low-carbon technologies shifted the energy assemblage.

Assemblage shift 1: Struggles related to framing the wind power assemblage as a policy object

A quick glance at the development of the Danish energy system assemblage since 2000 reveals that wind power has gained an increasingly important position. Figure 26.1 shows the growth in total wind power installations in Denmark from 1990 to 2020 (projected). In 2015, installed wind power accounted for approximately 5 GW of the 13 GW total electricity capacity generated by wind power, small and large scale power plants, and independent producers. Wind power is seen as the new core element in the future energy system, and many actors expect an installed base of 11 GW by 2030.[30] In 2015, wind-generated electricity accounted for more than 42% of total electricity production.

The process by which wind power came to play an increasingly central role was not a smooth one. While growth was high (25%) between 1994 and 2003, development was flat from 2004 to 2010/2011, before it started growing again through the beginning of 2016 with expectations for continued growth until 2020. These shifts in growth rates show the immediate effects of shifts in governments. The social-democratic coalition governments have supported wind power, whereas the centre-right governments have sought to stop or reduce wind power development immediately upon taking office.

In this section, we demonstrate how the shifts in political agencies (i.e., social-democratic governments versus centre-right governments) have been associated with the promotion of different calculative devices and valuation frames for wind power. These valuation frames have been used to assign different industrial and economic values to wind power vis-à-vis other energy technologies.[31]

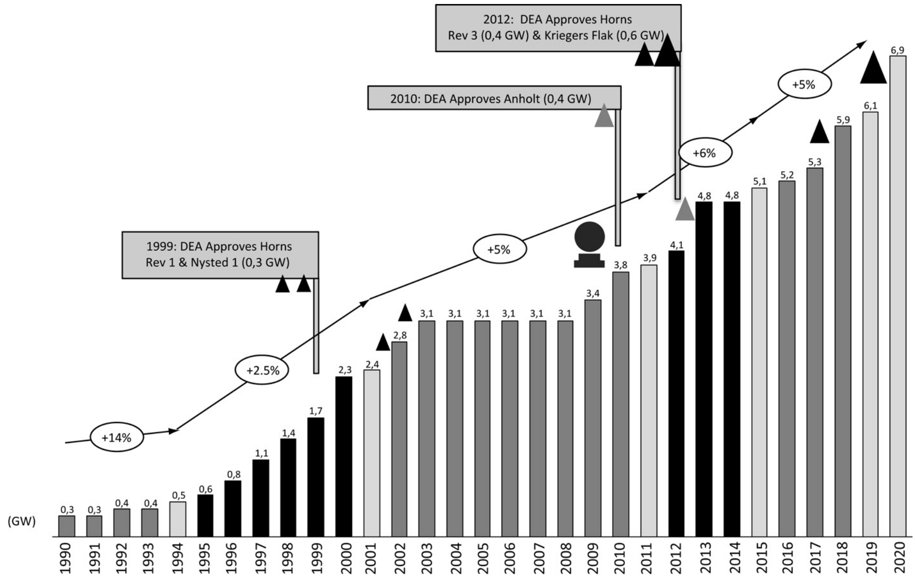

Figure 26.1 The increased installation of wind power in Denmark (1990–2015) and projected installations (2016–2020).

Note: The bar colours indicate a centre-right (in grey) or social democratic (darkest) government in office in a given year. The lightest bars represent election years. Black lines show the compound annual growth rate for given government term. The triangles show connections between the approval and installation years for Denmark's three important offshore wind farms (Horns Rev, Nysted, and Anholt) and those expected to be installed by 2020 (Horns Rev 3 and Kriegers Flak). The colours indicate under which government they were approved to be built. The grey circle represents COP15 held in Copenhagen in 2009.

A critical component in the strong (25%) growth of the wind power assemblage from 1994–2002 was a climate policy rooted in a new valuation frame promoted by the new social democratic Minister of Energy and Environmental Affairs, Svend Auken. Coming into government after the centre-right government (1991–1993) unsuccessfully sought to stop wind power development in Denmark, Auken's response was to create a 'super ministry' by combining the strong Ministry of Environment with the Ministry of Energy. This reorganization enabled biological and technical expertise in environment and energy to be combined and serve as a policy platform. For example, in 1988, the Ministry of Environment had already presented a calculation-based report on the consequences of CO_2 emissions that was used in the 1990 Energy Plan. The Auken regime successfully forged strong new linkages between renewable energy (most notably wind power development), CO_2 reductions and industrial policy cluster effects. The new Energy Plan of 1996, EP'21, built upon an explicit commitment to outputs of the 1995 UN Climate Convention (specifically, binding CO_2 reduction targets for industrialized nations) and further specified the development of industry and exports as key policy objectives. Auken was also a strong national and international promoter of the 1997 Kyoto agreement.

The valuation frame backing the policy for the wind power assemblage now consisted of two components. First, complex calculations in EP'21 produced a reality claim that wind power was valuable in relation to CO_2 reductions. Second, wind power was framed as being valuable as a strategic industrial cluster with high future employment, growth and export potentials that deserved to be protected and cultivated. This valuation frame, however, relied on a precarious network. First, it was dependent upon the highly charismatic and influential minister, Sven Auken, who successfully increased the budget of the 'super ministry' and prioritized climate and environmental concerns within the government. These policies enabled Danish wind power installations to grow from 3% in 1994 to about 13% by 2000. The Auken-regime, however, was increasingly criticized by the agency-network of the centre-right opposition in Parliament, which argued that expenditures on environmental policy were growing disproportionately.

The shift to a centre-right government in 2001 paved the way for a dramatic shift in the valuation frame of wind power. The centre-right coalition government stopped the development of two planned off-shore wind farms, and enacted savings of more than 2.5B DKK (2015 currency) in the 2002 state budget. In addition, the farmer-friendly government had an explicit policy to reduce governmental involvement in environment and climate issues and terminated more than 400 jobs related to those activities in 2002 alone.[32] The Danish Centre for Alternative Societal Analysis (CASA) later released a report based on proposed environmental cuts from the financial ministry, indicating that budget cuts to environmental activities would total between 21B and 26B DKK (2015 currency) from 2002 through 2005.[33]

The shift in government enabled the increasingly powerful Ministry of Finance to replace the 'hands-on' industrial policies based on strategic support to prioritized industries with more neo-liberal, 'free-market', 'hands-off' policies. Energy sources would now be judged on their ability to 'compete' in what was perceived as a 'subsidy-free market'. The hands-off policy approach penetrated the environment and energy domain under the guise of socio-economic analysis, which constituted a new calculative device for producing 'realities' that enabled environmental policies to be evaluated.[34] This socio-economic calculative device was not used to address ecological or resource-related issues, but to compare and contrast the economic efficiencies of various policies, and the extent to which they constituted a liability to the broader national economy. Further, in order to ensure that environmental activities would not once again spin out of control, the government established an environmental assessment institute in 2002. Climate sceptic Bjørn Lomborg, with the declared goal to evaluate the socio-economic cost-effectiveness of environmental policies using socio-economic analysis, headed the institute. Lomborg resigned in 2004 after strong critique of the quality of the reports, but created the 'Copenhagen Consensus Centre' think tank in 2006, which would receive funding from the annual budget of 2007 and onwards. In total, the centre-right wing government supported Lomborg and his affiliated institutions with more than 138 m DKK from 2002–2011.[35] It would be the new environmental minister of the Social-Democratic-led 2011 government Ida Auken, Svend Auken's niece, who would lead the way in removing what she categorized as 'ideologically-based funding' to Lomborg.[36]

This dominant new valuation frame based on the optimal allocation of resources given the assumption of a perfect market provided a new reference point for governmental policies related to the wind power assemblage. Yet it also paved the way for new struggles and contestation among various economic experts over the basic elements in any valuation process (i.e., what counts and how it counts).[37]

For example, the socio-economic analysis produced by the Ministry of Finance (2001) showed that investments in wind turbines were, in fact, associated with considerable positive socio-economic effects, mainly because the value of reductions in local air pollution was included in the calculation. Members of the independent and prestigious Danish Economic Council were critical and concluded that the analysis suffered from a series of methodological flaws.[38] First, they argued that the amount of pollution associated with electricity production from traditional thermal power plants had been overestimated, thus the environmental benefit of wind power had been overestimated as well. Second, they argued that the initial analysis had ignored so-called market distortion effects associated with tax-based financing of subsidies for wind power production. This suggested that the societal cost of wind power production had been underestimated. By re-calibrating the calculative device, the council concluded that wind power had negative socio-economic effects and thus constituted a societal liability. Their analysis further indicated that national climate policy goals could be more cost-effectively addressed by taxing fossil fuels and reducing CO_2 emissions abroad. Drawing on neoclassical supply-side economics, the analysis 'naturally' questioned the industrial policy cluster framing of the wind power industry that had been a key component of the governmental valuation frame during the 1990s.

In this new valuation frame, wind power was valued as an object in a socio-economic efficiency contest rather than in an industrial cluster driven by CO_2-reducing climate policies. This change reframed wind power from a potential future industrial stronghold into a societal burden. This conclusion can be seen as inevitable or tautological in the sense that all industrial policy is inappropriate, because the market is assumed to be perfect.

Competing valuation frames and policies in Denmark

The valuation frame of the Auken regime turned the IPCC report and CO_2 emissions into salient reference points for energy/climate policy and industrial cluster policy, and resulted in strong growth in wind power. The centre-right government shifted the valuation frame in 2001, and the socio-economic calculation approach contributed to legitimizing a drastic reduction in the influence and budget of the Ministry of Environment and Energy. Also, the new government cancelled the construction of two new offshore wind farms. However, due to pressure from social democrats, the socialist people's party, and the social liberal party, the centre-right government enacted a new political agreement in 2004 and resumed development of the two offshore wind farms that had been cancelled in 2001.[39] The centre-right accepted this for pragmatic reasons, namely, the continued importance of environmental concerns among voters and the importance of exporting wind turbines and other energy and environmental technologies.

The centre-right policy was criticized by the wind turbine industry and other spokespersons from the pro-climate policy network of actors, but the majority of industrial actors and related interest organizations did not criticize the drastically reduced policy ambitions and the diminishing expertise and power of the Ministries of Environment and Energy (which were separate once again). However, members of the centre-right began to change their position around 2006 when Denmark was chosen to host the COP15 meeting in Copenhagen in 2009. For example, the conservatives shifted their position in 2006 to embrace more decarbonization climate policies, highly driven by Connie Hedegaard, the new Minister for Climate Affairs (she later became the EU Commissioner for Energy and Climate, 2010–14). The year before COP15, in the autumn of 2008, the strong-minded anti-climate change Prime Minister Fogh Rasmussen announced at a public party meeting that 'I have very long belonged to those who were a little in doubt about climate change' and he went on to say 'that was maybe wrong … many of us have been cautious if not to say a little foot-dragging in all of this … We (Venstre party) have not been the climate policy avant-garde'.[40] As part of this shift in interest and orientation the government created a Climate Commission (2007–10) to establish whether it was possible for Denmark to have a 100% renewable energy system by 2050. However, except for some 'paper tigers' about future energy strategies, there were no further shifts in policies before the new social-democratic government took office in 2011.

The new charismatic Minister for Climate and Energy, Martin Lidegaard (who had been director of the green think tank CONCITO) followed Auken's policy approach and used new knowledge from the Climate Commission (and CEESA) to support the further transition of the energy system. The important 2012 Energy Act specified the overall energy policy until 2020, and represented a continuation of the valuation frame of the 1990s. The act promoted increasing energy efficiency, incorporating more renewables (biomass, biogas and wind power) into the energy supply, and funding energy research. There was no direct link between new calculative devices and shifts in policies, as little attention was paid to socio-economic calculations in the execution of the agreement, and green energy technology was once again framed as an important industrial cluster. The communication thus emphasized: 'The initiatives in the agreement generate green growth until 2020 and take the competitiveness of businesses into account.'[41] Longsighted 'points of orientation' were further defined as part of the agreement in an attempt to stabilize expectations and policy commitment to the energy system transition. These stipulated that 50% of electricity should be generated by wind power by 2020, that electricity and heat should be CO_2-neutral by 2035, and that the entire energy system (including transportation) should be CO_2-neutral by 2050.

In summer 2015, however, the new centre-right government took office and implemented their green realism policy approach, questioning the 2012 re-establishment of associations between these 'points of reference for action'. Denmark experienced a déjà-vu of 2002, as the annual state budget for 2016 included cuts to environmental activities both in Denmark and in the poorest areas of the world. The cuts amounted to more than 1B DKK (2015 currency) and were combined with the elimination of numerous environmental taxes and regulations, in particular to help the agricultural sector.[42] Further, green realism re-politicized the cost of transitioning towards a renewable energy system.

Splitting the bill in 2015: the PSO controversy and re-politicization of the transition cost

Right-wing politicians and some members of industry have once again framed the development of wind power as a burdensome societal cost. Wind power has been framed as a burden, exemplified by an extra cost component introduced on the electricity bills received by all consumers in Denmark. This so-called PSO (Public Service Obligation) is a tax that finances the feed-in tariff that ensures investors and owners of renewable energy sources (wind turbines, solar panels, biogas, etc.) receive a minimum price for electricity.[43] The PSO covers the gap between the feed-in tariff and the electricity market price, and consequently, the higher the market price on electricity, the lower the PSO and vice versa. The Merit-Order-effect and the low CO_2 prices (adding to the cost of fossil fuels) reduce electricity market prices, and this tax has increased in recent years. Critics have argued that the tax constitutes a critical economic burden to electricity-intensive industries such as horticulture and cement production.

This argument has not gone unchallenged, however. One counterargument has been that even when the energy tax is included, the Danish electricity price is still highly competitive in the European context. Another counterargument is that the PSO serves as an economic market incentive to become more efficient (i.e., as a green energy technology facilitator) because the PSO is part of a set of regulations for a favourable and predictable domestic market for new products and services.

To eliminate the argument that the PSO is a 'cost burden' for industry, some green realism advocates seek to shift the PSO from consumers' electricity bills to the state budget. Some smart energy system advocates see this as a smart way to 'constantly politicize' the funding of the transition to wind power and other renewables like solar power and heat pumps.[44] If the PSO is part of the state budget, the transition funding will have to compete with other issues such as social welfare benefits, investments in education and research, and tax cuts for low or high-income groups.

Since the EU is scrutinizing all national subsidy programmes related to energy technologies for treaty violations, there is considerable 'interpretative flexibility' for these subsidy programmes.[45] The green realism coalition has used this review to claim that the Danish PSO model violates the EU treaty. However, the EU has not confirmed this, and since most programmes can be adjusted to conform to the EU treaty, this is an example of the politicization of an important policy instrument.[46]

Summary of assemblage shift 1: valuation frames and policy objects

Competing valuation frames have constituted organizing nodes in the configuration of the networked agencies that make up the Danish wind power assemblage over the past four decades. These different valuation frames have turned wind power into different policy objects. One valuation frame driven by social-democratic governments has facilitated networked agencies configured around the climate change agenda and a clustered approach to the wind power industry. Since the early 1990s their tactic has been to enrol members of the green tech industry and energy utilities in this valuation frame.

The competing valuation frame of the centre-right governments has facilitated networked agencies based on socio-economic efficiency criteria, downplayed the importance of responding to climate change, and represented the wind power assemblage as a liability to economic growth and industry competitiveness. This valuation frame has been supported by the new socio-economic calculation method promoted by the powerful Ministry of Finance, and has attracted the support of agriculture and electricity-intensive industries. From 2001 to 2012 or so there was very little critique of this less ambitious, rolling-back centre-right climate policy from industry-based actors, except those in the wind turbine industry.

These struggles over which valuation frame to use as the basis for policy formulation illustrate that wind power has been subject to continuous political contestation. However, as we shall see in the next sections, there are two materially-based changes in the 2015 sociotechnical energy assemblage that constitute a very different context for this ongoing policy valuation struggle compared to 15 years ago.

Assemblage shift 2: wind power as a materially-based systemic concern in the electricity assemblage

The centre-right government reframed the wind power assemblage as a socio-economic 'efficiency' policy object just as an important material shift in the energy system assemblage became manifest. While electricity from wind power contributed less than 0.2% of Danish electricity production in 1981, this share had increased to 2% in 1990 and 13% in 2000. When electricity from wind turbines only contributed a marginal share of total electricity production, wind power electricity was considered to be of limited importance to the broader architecture of the electricity system as well as the energy system as a whole before 2000. The share of electricity produced by wind power, however, was rapidly increasing, and the average size of installed wind turbines increased from 150 kW in 1990 to more than 600 kW in 2000 (and subsequently increased to about 1.5 MW in 2010). Wind power was indeed becoming a 'large-scale' material penetration, and a new phenomenon emerged, as documented by articles in the Danish media and in the journal *The Engineer* stating, 'Denmark is flooded with excess electricity'. Only transmission lines to Norway and Sweden assure that someone used the power – but at a very low price.

Thus, by 2000, main actors within the energy system began to recognize that electricity from wind turbines was no longer an innocent source of energy that could be readily absorbed by the existing electricity system. Some had previously warned of the potentially disruptive consequences of wind power. When the 1981 Energy Plan noted the possibility of achieving 10% wind power by 2000, the electric utilities voiced concerns. In a research report published in 1983 based on a simulation of 600 MW of wind power in the electricity system, the utilities concluded that the unpredictability of wind power made it an unreliable source of energy, and further stated that wind power would result in 'certain operational disturbances, the solution to which requires extra expense' (our translation).[47] The report thus warned:

> The production from a wind power generation system will be characterized by limited predictability (contrary to the electricity load [i.e., demand]), and frequent and often strong variations. When the regulation of power plants is characterized by inertia, there can be difficulties in balancing the production of the power plants in relation to the wind power production and the electricity demand. (our translation)[48]

The challenge of integrating 'unpredictable' wind power into an electricity system designed to be run by 'predictable' power generation, however, was only realized and articulated as a pressing material concern after 2000. This articulation was the result of a report commissioned by the DEA in 2001 from involved stakeholders – including wind turbine owners, electric utilities, TSOs, the Organization for Renewable Energy, and experts – to analyse the system problem and come up with solutions to excess electricity.[49] The experts invented the new term *critical excess electricity* to describe new situations in which the electrical load cannot be consumed within a given area and other power plants have difficulty in reducing production further, making export the only option to avoid critical system failure.

Excess electricity is linked to a phenomenon called *technically bounded electricity generation*, which occurs when power plants produce electricity when there is demand for heat. While this electricity generation could compensate for a lack of wind, both heat demand and wind speeds are high during the winter months, which has the net effect of putting too much electricity into the grid. Power plants cannot regulate their power generation down, and since wind turbine owners have priority rights to generate electricity, grid load balance is threatened. There are two types of excess electricity: exportable and critical. While exportable excess electricity can be sold if there is capacity in transmission lines out of the load balancing area, critical excess electricity would cause a system breakdown 'if an actor did not step in and regulate the generation or demand'.[50]

Critical excess electricity defined a completely new situation, since the category did not exist in the regulatory framework of electricity supply law. Consequently, there were no legal provisions that allowed the transmission system operator (TSO) to regulate critical excess electricity.[51] The new systemic concerns were materially based, and provoked different programmes aimed at optimizing the energy system for wind power. For example, research by wind power integration experts demonstrated that the technical problems and integration costs depended on the complementarity of existing technologies in the energy system.[52]

The share of wind-generated electricity continued to increase, reaching 18% in 2005 and 22% in 2010. Consequently, the electricity market for traditional thermal power plants decreased. Power plants that continued to operate improved their technical flexibility by building heat storage capacity and electrical heaters, which enabled them to considerably regulate power generation on short notice in order to more efficiently respond to fluctuating pricing in the electricity market. Wind power was materially becoming an increasingly critical component of the overall energy system assemblage; as a result, pressure was mounting to redesign other components of the broader energy system.

New system concepts and new agencies: from a smart grid to smart energy systems

These material and economic challenges pertaining to wind power integration fostered new agencies centred on the search for concepts to address system problems. The first generation of system concepts, the *smart grid*, began to be promoted in mid-2000 by different consortia of researchers, energy distribution companies and companies in the IT field. Within the smart grid framework, wind power was viewed as an integration challenge pertaining to the electricity sector alone. The main strategy was to solve the integration puzzle by developing a 'smarter' demand side that could 'shave the peak loads' and shift electricity consumption from high to low price periods. Advocates argued that a 'smart' demand side response could be facilitated by an 'intelligent' electricity infrastructure aided by modern information and communication technologies that combine price signals with data from smart meters and intelligent electric appliances. However, Danish research projects in the smart grid tradition (I-Power, Eco-Grid, CITIES, Smart Energy in Cities) concluded that the material effects of the demand side responses were much more limited than anticipated, as they had little economic value. This was partly due to 'over-designed distribution cables' and failed attempts to push for increased electrification of transportation (electric vehicles) and heating (heat pumps) infrastructures.

To address the perceived shortcomings of the smart grid approach, the Energy System Research group at Aalborg University promoted a broader *smart energy system* approach[53] based upon interdisciplinary studies in Coherent Energy and Environmental System Analysis.[54] Instead of viewing the electricity system in isolation, the smart energy system framework redefines the boundaries of the energy system to include infrastructures related to electricity, heating and gas, and end user domains of energy services related to transportation, heating and industry. Only such a radical shift can facilitate the development of sufficiently responsive complementary technologies in a low carbon energy system based on fluctuating wind power. This requires that the TSO strategy must strike a new balance between investing in transmission lines to neighbouring countries (increasingly also with wind power) and investing in integration of the national energy system.

Disruption and redesign of the electricity market

Another critical system component that came under pressure due to the increasing penetration of wind power was the Nordpool electricity market platform that has been operated jointly by the Nordic TSOs since 2001. In spring 2014, the Danish TSO organized a meeting with its stakeholders to discuss serious concerns that the traditional market model was breaking down.[55] Centralized power plants were struggling; between 2008 and 2015, 35% of traditional thermal power plants ceased operating.

The critical problem was that the high share of wind power (with zero marginal cost) drove down prices by shifting the supply curve relative to a given demand, which lowered the prices for all owners of power plants. This phenomenon, the *merit order effect*,[56] occurred whenever large amounts of low marginal cost wind power were added to the electricity market exchange, which had been designed to set prices in a market based on the marginal cost of fossil fuels. As a result, Nordpool set prices that were too low to support the business models of the power plant owners. The Danish TSO was especially concerned about the serious reduction in controllable capacity, as Danish power plants had closed with record speed due to these inadequate prices. A related issue was an expected increase in wind power in neighbouring countries, which was anticipated to drive prices even lower. Increased wind power in neighbouring countries would make it increasingly difficult to export excess wind power, since these areas also would be flooded by excess electricity from their own wind turbines.

In response to these market issues, a working group of stakeholders was assembled to outline a 'Market Model 2.0'. This working group concluded that the traditional market model was not well-suited to securing the flexibility and capacity of services in the new electricity system due to its inability to set accurate prices. The group thus stated a need to 'identify new "system-services" that could be priced so as to make them attractive for market participants'.

This new (revolutionary) 'understanding' spread rapidly throughout the electricity field. For example, at the EWEA (European Wind Energy Association) in Paris in November 2015, a professional from the IEA stated that building a plant to provide base-load energy is an old-fashioned way of thinking about load balancing problems and the economic value of electricity services, since future energy systems will need flexibility more than base-load.[57] Service flexibility was thus being framed as integral to the new approach to load balancing in the smart energy system.

The new climate policy normal: smart energy systems thinking

The smart energy systems concept constitutes a second generation framework that has become the dominant system framework among key actors within the energy system. The stabilization of this new system framing was supported by the 2012 Energy Act, which stipulated that the Danish energy system should become CO_2-neutral by 2050. Achieving this goal was expected to require a drastic increase in wind power capacity, which would make the integration challenge even more critical. Presently, the smart energy system philosophy forms the backbone of energy system concepts and scenarios promoted by actors such as the Danish TSO, the Danish Energy Agency, The Danish Energy Association and the Danish Society of Engineers. A climate council established to advise the government has further advocated the smart energy system approach as a cost-effective way of transitioning to a CO_2-neutral energy system.[58] Other analysts even argue that the transition to a smart energy system is socio-economically competitive with a continuation of the established energy system design. In recent years, the smart energy system approach has thus successfully cultivated a shared system framing that promotes fundamental transitions across the sectors of electricity, heating, gas and transportation with wind power as the core energy production technology.

No implementation plan for increased electrification

However, this increasingly shared system frame does not appear capable of ensuring a strongly coordinated transition. For example, inherent in the smart energy system approach is the need to increase electrification, especially in flexible consumption areas that are able to decrease consumption when wind speed is low and increase consumption when power production is high. An area with high potential for increased electrification is district heating, where large heat pumps are able to convert electricity to hot water very efficiently. Current investments are nevertheless directed towards biomass boilers, given tax advantages (zero taxation) over electrification (high taxation). The present Minister of Energy has refused to change the tax structure because during the election campaign those currently in office had promised not to increase taxes; moreover, reducing the electricity tax would negatively impact the public budget. This political stalemate in relation to tax reforms has been strongly criticized by the Danish district heating association, which has already perceived future changes in district heating due to the integration of wind power:

> We destroy our opportunity to take advantage of this situation and seize the production of large heat pumps because of the electricity tax. It is pure nonsense, says Kim Mortensen from the Danish District Heating Association. He can only say that rather than the efficient use of the state-sponsored wind energy in large heat pumps, then for example, Norwegians welcome the fact that the average export price of wind power is down to about 157 kr. per MWh. On the other hand, the Danes have had to import at a cost of nearly 212 kr. per MWh when the wind turbines have stood still, and the Norwegians have turned on the water power.[59]

This lack of coordination has been criticized by Kathrine Richardson, former chairman for the Danish Climate Commission (2007–10) who strongly warned the centre-right government not to reduce ambitions related to increased electrification of the demand side where technologies already exist (heat pumps, electric vehicles).[60] Despite the lack of coordination in some current investment patterns, the diffusion of the smart energy system concept as a shared system frame illustrates that wind-generated electricity is defining a new material reality for the system as whole. This new reality has now been established as a 'hard fact' among key actors of the energy system.

Summary of assemblage shift 2: materiality strikes back and intensifies the need to reconfigure the energy assemblage

In 2000, the stronger material presence of wind power began to have increasingly obvious repercussions on the hitherto well-functioning – and since 2001, market-based – electricity system. The fluctuating nature of wind power generated critical mismatches between technological, market and regulatory elements linked to the established electricity generation assemblage. The material presence of wind power fractured old understandings of the system and created a need to frame new (ontological) realities. New agencies were cultivated within the energy system assemblage and they began to construct new system vocabularies.

Now, it is no longer considered possible to discuss wind power integration without viewing the energy system as a whole. From this new material reality, the smart energy system concept has emerged as one response, and wind power has been framed in such a way that wind power development and energy system development have become inseparable. This new framing has shifted perceptions of wind power mainly as a system problem to being framed as the central organizing component in the future low carbon energy system. For example, the existing infrastructures in district heating and gas have been creatively assigned new roles, and are to be reconfigured as assets for a wind-powered low carbon energy system. Denmark did not originally invest in gas infrastructure and co-generated district heating to facilitate the integration of wind power, but has benefited from lucky timing.[61] Countries such as Germany, the UK and China do not have existing assets like district heating infrastructures that can become relatively cheap assets for integrating large shares of wind power.

The smart energy systems framing suggests the need for a fundamental rebuilding of the energy system assemblage, not only with new technologies but also with new regulatory strategies and market arrangements able to facilitate a commercially based, efficient low carbon energy system.

Assemblage shift 3: shifting political coalitions and the new material grounding of the industrial cluster in policy

Under the green realism campaign, the right wing government elected in 2015 problematized the ambitions, speed, and directions of the energy system transition outlined in the 2012 Energy Act with reference to socio-economic considerations and the burdens of higher energy prices on industrial competitiveness. Danish energy and climate policies have never resulted from ambitions linked to a stable and strong national consensus in Parliament. While there have been compromises with broad political support, the ambitions in these compromises have always been driven by a coalition of the left wing, social liberals, and the social democrats. The cocktail of renewable energy and new jobs has been important for the left wing and social liberals since the 1970s, and the social democrats joined wholeheartedly in the mid-1980s. Since then, the coalition has strongly supported renewable policies and has had high ambitions to challenge the existing energy sector and use strong policy instruments (e.g., the energy policy goals from 1981, wind power market stimulation, and coercive regulation of electric utilities). In opposition to this political framing of the energy system assemblage, a centre-right coalition comprised of liberals, conservatives and the Danish people's party, has always been sceptical about the need for radical new energy policies, the promotion of renewable energy, and coercive regulation of the energy sector.

New allies and a new material grounding of the industrial cluster in policy

The relative influence of these competing framings of the energy system assemblage, however, is also rooted in the extra-parliamentary socio-technical collective of actors from grassroots and industry, science, and the media. Ever since the 1970s, NGOs and grassroots movements with direct connections to left wing parties have been active in the public arena. They have made allies with prominent Danish researchers who have used their expertise and academic positions at universities to strengthen and legitimize their claims. Similarly the pro-nuclear and anti-wind power movements formed a socio-technical collective by joining forces with prominent researchers in physics, engineering and economics, and were supported by the media in newspaper editorials. In the 1970s, the Danish Industry Association supported nuclear power, not only because it could produce cheap energy, but also because of the potential for Danish industry to help build nuclear power plants and thus upgrade the scientific and technological capacities of companies and research institutions.[62] Political framings of the energy system assemblage are thus highly dependent on strong alliances with extra-parliamentary agency networks.

An outcome of the ongoing reconfiguration of the energy system assemblage has been the development of a new and increasingly active collective of business and industry actors involved in the production of green energy technologies such as wind power, biogas and district heating. Energy system-related green tech companies focused on wind power, district heating and automated regulation systems have been growing rapidly and now constitute a high value sector of the economy. Since 2005, the collective formed by these green tech industries has been increasingly promoting itself using industrial cluster arguments cultivated by left wing governments during the 1980s and 1990s concerning the future employment and export potential of a wind-based transition of the energy system.

This collective has made it increasingly difficult for right wing governments to speak 'on behalf of industry', when criticizing governmental support of the energy system transition. Today, the tables have turned, and green realism is facing criticism from industry. This criticism is not only voiced by the usual suspects from the wind turbine industry, but from an increasingly broad range of industry actors who were initially sceptical about the low carbon energy system, but now see it as a fundamental part of the future based on revenues from new goods and services. These new critics exemplify a tipping point-type shift in the energy assemblage, the cumulative effect of many small and gradual changes that have strengthened business engagement in and commitment to the energy system transition. Many business actors seem to have completely shifted position in favour of the transition.

This new collective of industrial actors argues that numerous new business opportunities are associated with the transition to a new low carbon energy system, but that these business opportunities rely on stable boundary conditions for the market arrangements that are going to finance them. Especially after the 2012 Energy Act, business actors shifted their framing of future investment opportunities towards the green, low carbon renewable energy system. For instance, commenting on green realism, the CEO of Grundfos, the world's largest energy-efficient water circulation company, stated, 'Too bad the ambitions have been lowered on environment and climate – and the timing is so bad before COP 21'.[63] Likewise, the CEO of Siemens Wind, which has 10,000 Danish employees, argued that Denmark should not reduce its offshore wind power ambitions: 'We would like to have R&D and production jobs in Denmark, but Denmark must think green and global.'[64] Former EU Climate Commissioner Connie Hedegaard joined this public debate, stating, 'We are repeating Fogh's mistakes', and pointing out that Denmark is losing industrial leadership positions associated with the transition to the green economy while other countries are accelerating their investments.[65]

The strategic industrial cluster thinking is also supported by the labour union. Their newly established green think tank reported, 'There are up to 55,000 new jobs in green transition'.[66] The green think tank is headed by a former head of the Ministry of Finance during the 1990s who has been a key spokesperson for green transition policies. He later became CEO of the state-owned energy company DONG, where in 2006 he announced a bold initiative: by 2030, 85% of DONG's power generation will be from renewable resources (most notably wind), and 15% from fossil fuels, a dramatic shift from the 2006 proportion of 85% from fossil fuels and 15% from renewable resources. DONG has since become a world leading developer and operator of offshore wind power, thereby becoming a new powerful spokesperson for the continuation and acceleration of changes in the assemblage to accommodate the low carbon energy system. Importantly, the new engineering and business competencies in offshore wind power stem from the series of coercive political acts since the first 100 MW agreement in 1985 that have incentivized Danish electrical utilities to invest in on- and offshore wind power. Coercive regulations forced them to do things that they did not like, but the competences they gained in the process now form the basis for their leading global position.

Summary of assemblage shift 3: homogenous industrial opposition to green realism

The gradual materialization of clean-tech based revenue streams among many industrial companies has fostered rather homogenous industrial opposition to green realism. This new clean-tech voice is materially anchored in interests, competences, and expectations related to new future business opportunities for clean-tech products and services.[67] In short, the identities of many agencies in the Danish industry have been transformed due to their increased involvement with the gradual transformation of the energy technology assemblage.

Conclusion: shifting assemblages where the present government is out of sync with materially-anchored concerns and interests in the present state of the assemblage

In this chapter, we have used the relational assemblage perspective to provide a kaleidoscopic picture of some diverse shifts in the Danish transition towards a low carbon energy system. The socio-technical assemblage is not a fixed entity, but an 'open building site under constant construction' made from *new relational constellations* of heterogeneous actors and intermediaries that shape, contest, and define each other's technologies, cognitions, interests, and identities.

An important thread in the Danish transition has been the competing networks of the assemblage associated with the social-democratic and centre-right dominated governments, which have used competing valuation frames as reference points to legitimize their energy and climate policies. Another important thread has been the material dimension associated with the penetration of wind power in the electricity system and revenue streams from clean-tech products and services.

The materiality dimension has enabled us to see that the green realism approach promoted by the centre-right government has been confronted with new agencies that respond to new material and discursive realities. These realities involve both a new system concept (i.e., the smart energy system) aimed at solving the material systemic problems of wind power integration, and include new business opportunities and industrial transformation associated with investing in the goods and services that will comprise the future low carbon energy system. The agencies involved in the reconfiguration of the Danish energy system assemblage did not come from outside contexts or structures. New agencies were assembled as embedded actors struggled to cope with difficulties and tensions associated with their own socio-material engagements in the system. Since 2000, this interrelatedness has been transformed from being framed mainly as a 'system problem' or 'system cost' to being framed as a source of 'industrial innovation' and as a driver of a societally desirable system transition.

In addition, the smart energy system concept seems robust, as it is associated with a new climate policy normal. Indeed, major actors in the energy assemblage (TSO, IDA, DEA, energy analysts, engineering consultancies) are converging on a framework of the future low carbon energy system with wind power as the central technology. Even if the Danish centre-right government with its focus on green realism once again seeks to roll back or even stop climate policies, the increasing socio-material momentum in the assemblage is making it more and more difficult for them to do so.

Wind power has been transformed from 'white noise' with no meaning and relevance for the broader configuration of the system assemblage into the centrepiece of the new climate policy normal, understood as broad acceptance of a transition towards a low carbon energy system by 2050 – a renewable energy system based on wind power. Wind power is no longer a hippie thing or a relic from the past, but has become a valued technology that can save society from the damage caused by CO_2 emissions from the fossil fuel-based energy system. Wind power has also become a 'material irreversibility' that has triggered new concerns and provoked actors to construct new agencies. Controversies over next steps characterize the current situation as Denmark heads toward achieving a low carbon energy system by 2050. The smart energy system will become a battlefield as diverse actors seek to defend their existing positions; but more than likely, green realism will delay rather than derail the further transition towards a wind-oriented reconfiguration of the energy system assemblage.

The key objective of our analysis has been to understand how the Danish energy technology assemblage was reconfigured through the construction of new agencies. In particular, we have shown how the process of transformation has been modulated through relational interactions and tensions among agencies and their valuation frames, and how these processes have enabled *actors to re-frame themselves and their actions* through new socio-material concepts and narratives that ascribe new roles to individual components of the system. The assemblage perspective has enabled us to give this account from an 'open building site' by capturing the incompleteness, multiplicity and struggle involved when emergent networks of distributed agencies seek to mobilize and enrol new allies in order to stabilize their sociotechnical worlds.

From an agency-based assemblage perspective, renewable energy transitions are no different from former historical societal transitions associated with centralized electricity generation, sanitation, and mobility realized with a particular transportation system based upon fossil fuels in individual automobiles.

Notes

1 We thank Henrik Bach Mortensen, Peter Karnøe's industrial PhD student, for creating Figure 26.1, finding important data, and providing helpful comments on this manuscript.
2 http://energinet.dk/DA/El/Nyheder/Sider/Dansk-vindstroem-slaar-igen-rekord-42-procent.aspx.
3 German Watch, https://germanwatch.org/en/download/10409.pdf.
4 Peter Karnøe, 'Large-Scale Wind Power Penetration – Breaking Up and Re-mixing Politics, Technologies, and Markets', *La Revue de l'Énergie* 64, no. 611 (2013).
5 A. Smith, and A. Stirling, 'Moving Outside or Inside? Objectification and Reflexivity in the Governance of Socio-Technical Systems', *Journal of Environmental Policy and Planning* 9, no. 3–4 (2007): 351–373; J. S. Jensen, 'Framing of Regimes and Transition Strategies: An Application to Housing Construction in Denmark', *Environmental Innovation and Societal Transition* 4 (2012): 51–62.
6 T. Mitchell, *Carbon Democracy: Political Power in the Age of Oil* (London and New York: Verso, 2011); Catherine Mitchell, *The Political Economy of Sustainable Energy* (London: Palgrave MacMillan, 2010); F. W. Geels, 'Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-level Perspective and a Case-study', *Research Policy* 31, no. 8–9 (2002): 1257–1274; G. C. Unruh, 'Understanding Carbon Lock-in', *Energy Policy* 28, no. 12 (2000): 817–830.
7 W. E. Bijker, T. P. Hughes, and T. J. Pinch, *The Social Construction of Technological Systems* (London: MIT Press, 1987); M. Callon, 'Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St Brieuc Bay', in *Power, Action and Belief: A New Sociology of Knowledge?*, ed. J. Law (London: Routledge, 1986), 196–223; W. Bijker, and J. Law, *Shaping Technology/Building Society: Studies in Sociotechnical Change* (London: MIT Press, 1992).
8 M. Callon, *The Laws of the Markets* (Oxford: Wiley-Blackwell, 1998); M. Callon, F. Muniesa, and Y. Milo, eds, 'Introduction', in *Market Devices* (Oxford: Wiley-Blackwell, 2007); N. Fligstein, *The Architecture of Markets* (Princeton, NJ: Princeton University Press, 2001).
9 R. Garud, and P. Karnøe. 'Bricolage versus Breakthrough: Distributed and Embedded Agency in Technology Entrepreneurship', *Research Policy* 32 no. 2 (2003): 277–300.
10 M. Callon, 'Techno-economic Networks and Irreversibility', in *A Sociology of Monsters? Essays on Power, Technology, and Domination*, ed. J. Law (London: Routledge 1991), 132–161; J. Law, *After Method: Mess in Social Science Research* (London: Routledge, 2004); B. Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (Oxford: Oxford University Press, 2005).
11 Callon, 'Techno-economic Networks and Irreversibility'; J. Markard, S. Wirth, and B. Truffer, 'Institutional Dynamics and Technology Legitimacy: A Framework and a Case Study on Biogas Technology', *Research Policy* 45, no. 1 (2016): 330–344; S. H. Kim, and S. Jasanoff, 'Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea', *Minerva* 47 no. 2 (2009): 119–146.
12 M. Callon, 'What Does it Mean to Say that Economics is Performative', in *Do Economists Make Markets?*, ed. D. MacKenzie, F. Muniesa, and L. Siu (Princeton, NJ: Princeton University Press, 2008).
13 T. P. Hughes, *Networks of Power: Electrification in Western Society 1880–1930* (Washington, DC: Hopkins University Press, 1983).
14 R. Garud, and P. Karnøe. 'Bricolage versus Breakthrough: Distributed and Embedded Agency in Technology Entrepreneurship', *Research Policy* 32 no. 2 (2003): 277–300.

15 Unruh, 'Understanding Carbon Lock-in'; Hughes, *Networks of Power*.
16 N. Fligstein, and D. McAdam, 'Toward a General Theory of Strategic Action Fields', *Sociological Theory* 29, no. 1 (2011): 1–26.
17 L. Suchman, *Plans and Situated Action: The Problem of Human-machine Communication* (Cambridge: Cambridge University Press, 1987).
18 Law, *After Method*, 41–42.
19 Law, *After Method*; Latour, *Pandoras Hope – Essays on the Reality of Science Studies* (Cambridge MA: Harvard University Press).
20 Law, *After Method*; R. Garud, A. Kumaraswamy, and P. Karnøe, 'Path Creation or Path Dependence', *Journal of Management Studies* 47, no. 4 (2010): 760–774; Peter Karnøe, and R. Garud, 'Path Creation: Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster', *European Planning Studies* 20, no. 5 (2012): 733–752.
21 M. Rüdiger, *Energi i forandring* (London: DONG Energy, 2011), 43.
22 Rüdiger, *Energi i forandring*, 45.
23 Kim, and Jasanoff, 'Containing the Atom'; Hvidtfelt K. Nielsen, 'Tilting at Windmills: On Actor-Worlds, Socio-Logics, and Techno-Economic Networks of Wind Power, 1974–1999' (PhD diss., Aarhus University, 2001).
24 T. Pinch, 'Moments in the Valuation of Sound: The Early History of Synthesizers', in *Moments of Valuation – Exploring Sites of Dissonance*, A. Antal, M. Hutter, and D. Stark (eds), (Oxford: Oxford University Press, 2015).
25 N. I. Meyer, 'Politik og Vedvarende Energi', in *Vedvarende Energi i Danmark 1975–2000* (Renewable Energy in Denmark 1975–2000), ed. E. Beuse et al. (Aarhus, Denmark: Organization for Renewable Energy, 2000), 75–110.
26 Konrad Jensen, *Mænd i Modvind* (Copenhagen: Børsens Forlag, 2003).
27 Rinie van Est, *Winds of Change: A Comparative Study on the Politics of Wind Energy Innovation in California and Denmark* (New York: International Books, 1999); E. Beuse, et al. (eds), *Vedvarende Energi i Danmark 1975–2000* (Renewable Energy in Denmark 1975–2000), pp. 75–110 (Aarhus: Organization for Renewable Energy), available at www.ove.org.
28 P. Karnøe, and A. Buchhorn, 'Path Creation Dynamics and Winds of Change in Denmark', in *Promoting Sustainable Electricity in Europe*, edited by W. Lafferty et al. (Cheltenham: Edgar A. Elgar, 2008); M. Cohen, J. G. March, and J. P. Olsen, 'Garbage Can Model of Organizational Choice', *Administrative Science Quarterly* 17, no. 1 (1972): 1–25.
29 Peter Karnøe, *Danish Wind Turbine Industry – A Surprising International Success: On Innovations, Industrial Development and Technology Policy* (Copenhagen: Samfundslitteratur, 1991).
30 *Energikoncept 2030 – baggrundsrapport*, Energinet.dk, 2015, www.energinet.dk.
31 A. B. Antal, M. Hutter, and D. Stark, *Moments of Valuation: Exploring Sites of Dissonance*, 1st edn. (Oxford: Oxford University Press, 2015); D. Beunza, and R. Garud, 'Calculators, Lemmings or Frame-makers? The Intermediary Role of Security Analysts', *The Sociological Review* 55 (2007): 13–39; H. Mortensen, 'Calculating Wind Energy as Cost Burden or Cost Leader in Denmark' (working paper, Department of Development and Planning, Aalborg University, Aalborg, Denmark, 2015).
32 N. Nørgaard, and J. Tornbjerg, 'Finanslov: Sort dag for miljøet', *Politiken*, January 30, 2002, 7; J. Tornbjerg, 'Miljøet redder finansloven', *Politiken*, March 20, 2002, 4.
33 K. Vogt-Nielsen, and L. Husmer, *Dansk Miljøpolitik 2002: En analyse af VK-regeringens første måneder set med miljøbriller* (Copenhagen, Denmark: Center for Alternativ Samfundsanalyse, 2002).
34 K. Asdal, 'Enacting Things through Numbers. Taking Nature into Accounting', *Geoforum* 38, no. 1 (2008): 123–132.
35 Ritzau Note, *Information Newspaper*, 27 January 2011.
36 Ritzau Note, *Politiken Newspaper*, 2 November 2011.
37 D. Stark, *The Sense of Dissonance: Accounts of Worth in Economic Life* (Princeton, NJ: Princeton University Press, 2009).
38 Danish Economic Council, *Vismandsrapport, Dansk Økonomi*, Forår 2002, De Økonomiske Råd (Copenhagen: Danish Economic Council, 2002).
39 Only one of these two new offshore wind farms stipulated in the compromise of 2004 came online after extensive political delays, www.ens.dk/undergrund-forsyning/vedvarende-energi/vindkraft-vindmoller/havvindmoller/idriftsatte-parker-nye#Horns Rev II.
40 Authors' translation of the original quote from Danish: 'jeg har meget længe hørt til dem der var sådan lidt i tvivl om det der med klimaet … der er nok mange hos os der har været lidt forsigtige, for ikke at

sige fodslæbende i alt det her … Jamen, det var måske også forkert … man kan nok sige vi har ikke været den energipolitiske avantgarde.' Full text of the talk can be found in this source: http://ing.dk/artikel/fakta-laes-statsministerens-miljotale-93417-17.11.2008, retrieved June 17, 2016.

41 KEBMIN, Energiaftalen i korte træk, Klima-, Energi- og bygningsministeriet, 2002, 1.

42 H. P. Dejgaard, 'Miljø og klima rammes særligt hårdt i den store nedskæring af Danida Budget', *Ingeniøren*, 4 October 2015; D. Rehling, 'Grønt set er finansloven sort', *Information Newspaper*, 19 January 2015; 'Regeringen skærer 1,5 milliarder mere på ulandsbistand', *Information Newspaper*, 19 November 2015.

43 PSO stands for Public Service Obligation and PSO is in the context of EU law, that allows a governing authority to offer a special subsidy for a public service to a winning company, in this case renewable energy services. The PSO is offered because the so-called free-market cannot create incentives for the socially desired development. However, the so-called free market for fossil, nuclear and renewable energy is better seen as the political economy of energy markets as all fuels and technologies exist and are favoured by various state subsidies and regulations.

44 B. V. Mathiesen, H. Lund, D. Connolly, et al., 'Smart Energy Systems for Coherent 100% Renewable Energy and Transport Solutions', *Applied Energy* 145 (2015): 139–154.

45 Bijker, Hughes, and Pinch, *The Social Construction of Technological Systems*.

46 Margrethe Vestager, EU Commissioner for Competition, interview on Danish Radio, 22 January 2016, P1 Orientering, 9 minutes in.

47 DEFU, Vindkraft i elsystemet, Energiministriets og Elværkernes Vindkraftprogram, rapport EEV 83–02, September 1983, 2a.

48 Ibid., 2.3.

49 Danish Energy Agency, Omkostninger ved CO_2-reduktion for udvalgte tiltag – Midtvejsrapport, Energistyrelsen, May 2001.

50 Ibid., 8.

51 Ibid.

52 H. Lund, and E. Münster, 'Management of Surplus Electricity Production from a Fluctuating Renewable-energy Source', *Applied Energy* 76, no. 1–3 (2003): 65–74.

53 Mathiesen et al., 'Smart Energy Systems'; H. Lund, *Renewable Energy Systems: A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions*, 2nd ed. (Cambridge, MA: Academic Press, 2014).

54 H. Lund, et al., *Coherent Energy and Environmental System Analysis* (Aalborg, Denmark: Aalborg University, 2011).

55 www.energinet.dk/DA/El/Engrosmarked/Ny%20markedsmodel/Sider/default.aspx.

56 Pöyry, *Wind Energy and Electricity Prices: Exploring the 'Merit Order Effect'* (Brussels: European Wind Energy Association, 2010).

57 Henrik Mortensen, interview with author, 21 January 2010.

58 Klimarådet. 'Omstilling med omtanke – Status og udfordringer for dansk klimapolitik', Klimarådet.dk 2015.

59 'Dansk Fjernvarme: Værdien af vindmøllestrøm kan øges med milliarder med varmepumper', *Energy Supply, Online Newspaper*, June 9, 2015.

60 T. Færgeman, 'Der skal mere strøm på varmen', *Politiken Newspaper*, 28 September 2015, 9.

61 P. Pierson, 'Increasing Returns, Path Dependence, and the Study of Politics', *The American Political Science Review* 94, no. 2 (2000): 251–267.

62 P. Karnøe, and S. Møller, 'En analyse af udviklingsbetingelserne for udvalget energiteknologier – en magt og teknologianalyse' (master's thesis, Copenhagen University, 1985); H. Nielsen, K. Petersen, and Hans Siggaard Jensen, *Til Samfundets Tarv – Forskningscenter Risø's historie* (Risø: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi, 1998), 560.

63 T. Færgeman, interview with CEO Mads Nipper, *Politiken Newspaper*, 22 October 2015.

64 T. Færgeman, interview with Siemens Global off-shore director, *Politiken Newspaper*, 25 October 2015.

65 D. Saietz, *Politiken*, 4 November 2015.

66 Dansk Energi, '3F: Op til 55.000 arbejdspladser i grøn omstilling', Dansk Energi, 2015, www.danskenergi.dk/Aktuelt/Arkiv/2015/September/15_09_24B.aspx.

67 M. Borup, et al., 'The Sociology of Expectations in Science and Technology', *Technology Analysis & Strategic Management* 18, nos. 3/4, July–September 2006, 285–298.