The greening of European electricity industry: a battle of modernities

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Abstract

Europe has played the role of a green hegemon on the global arena for several decades. By exploring its green transition in the electricity industry, the article discusses whether Europe is on track with regard to delivering sustainable development in a core sector at home.

The article finds that the greening of European electricity industry has been highly dynamic and can best be represented in terms of competing modernities; where carbon, nuclear, renewables and demand side management challenge each other in the race for sustainable energy solutions.

The article describes Greening European electricity industry as a complex institutional game which resembles a relay race where various factors have driven innovation at different stages. Change may be initially have been politically driven, while the baton is later taken by markets, technology or civic mobilization. The article shows how strong greening policies may lead to blockage, whereas softer and less confrontational policies with triggering effects may have a better chance of success.

The article also argues that a central factor in the apparent European success in greening electricity has been an advantageous blend of technology push and market pull approaches, which has merged out of national rivalry rather than coordinated planning.

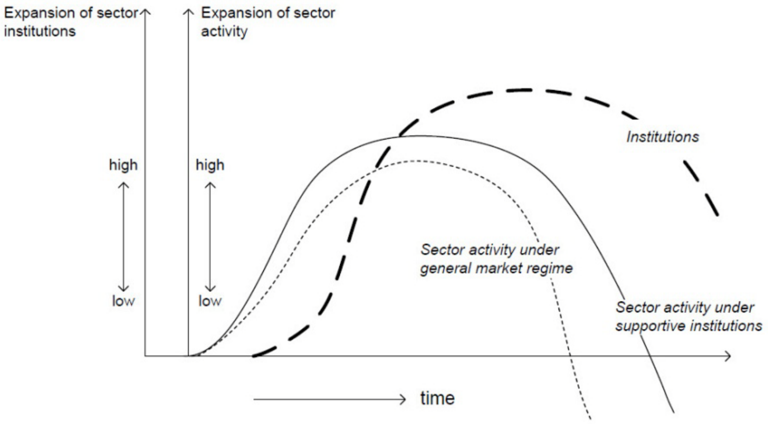
Transformation of large socio-technical systems

In a mature economy, such as that of Western Europe, as well as in the East-European catch-up economies, the buildup of an alternative green modernity is not a ‘greenfield’ operation, but a change of course or even a fundamental substitution of an existing large industrial system—a system which has been built up around core technologies and institutions bought into by the public and enhanced by supportive rules and regulations (a sociotechnical system) (Hughes, 1983). Radical and large scale change such as the transition to a post-carbon energy system, therefore involves emergence of rivaling techno-economic paradigms with competing technologies, business models and institutional regimes (Midttun, 1988).

Due to previous build-up of commercial interests, regulation and social buy-in to established technologies, the incumbent configuration usually carries considerable inertia. Sector-institutions enable it to protect itself from change, and maintain established economic and institutional patterns. Hence new green alternatives are destined to fight a tough uphill battle, where they will have to win the goodwill of policy-makers and regulatory authorities, convince industrial strategists, gain the confidence of investors and engage consumers.

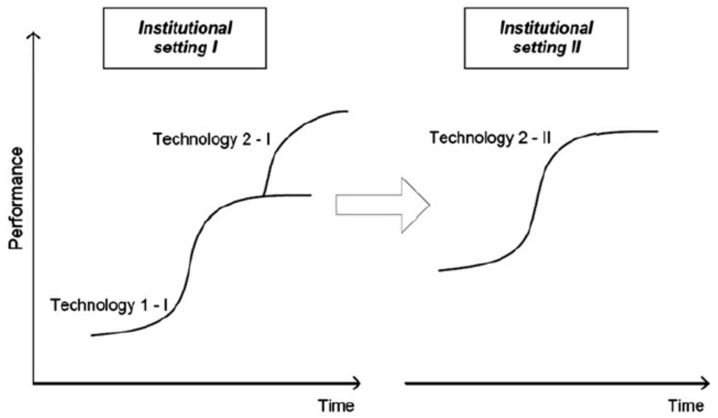
The dynamics of growth and transition of a large sociotechnical system can be illustrated in terms of a standard product cycle model with an institutional dimension added (Fig. 1). A new technology emerges and grows, and stimulates institution-building around it. Successful institution building in turn stimulates industrial growth (indicated by the shaded area ‘‘a’’). At the peak of its development, the sector emerges with a strong industrial base supported by strong sectoral institutions that allow it to expand and retain its position beyond what would have occurred under neutral institutions (indicated by the shaded area ‘‘b’’)

Fig.1. Illustration of the implications of institutional lag.
Source: Based on Midttun 1988.



Under full socio-technical alignment around a common technological paradigm, only one dominant product cycle exists. Under transition, however, multiple systems emerge in parallel, creating misalignment and potential realignment around alternative techno-economic paradigms. With analogy to technological innovation, one may speak of conforming or disruptive transformation (Christensen, 1997). System conforming transformation implies techno-economic transformation within the boundaries of existing institutions and vested interests. As illustrated in Fig. 2, the new paradigm appears as the prolongation of the old, as a new and better version, within the same institutional, social and commercial coordinates. Disruptive transformation, however, involves transformation also in the institutional setting, and creates disruptive change in business models, social practice and political regulation. Greening of the European electricity industry, in other words, is likely to provoke tensions and challenges not only at the industrial and technological, but also at the institutional level.

Fig. 2. Conforming and disruptive transformation (Based on standard S-curve theory; Christensen's (1997) concept of disruptive innovation and Midttun's (1988) theory of institutional lag).



The current transformation of the European electricity sector with regard to meeting the climate challenge involves several rivaling socio-technical paradigms competing for hegemony, one of which is a transformation of the incumbent carbon-technology into a low carbon future. The paper, therefore, presents the current remodeling of European electricity industry to meet the climate challenge as a battle of four modernities.

We have chosen the term ‘‘modernity’’ in a narrow sense, to indicate that all the rivaling paradigms advocate ‘‘modern’’ energy systems capable of carrying advanced high-tech welfare societies.[1] The earliest, carbon modernity, was built up since the late 1800s and through much of the 1900s as a way to power modern industrial society to allow it to produce mass consumer goods. The second, nuclear modernity, was launched as a civilian application of nuclear technology, which had been developed for military purpose during World War II. This peaceful application was envisaged to transcend the limitations of carbon based energy and move the world into a phase of nonpolluting energy-abundance. The third eco-modernity

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[1] Rather than centering exclusively on their technological basis, we focus on how energy-technologies are embedded in organisational arrangements and wider social and political ideas and visions.

emerged out of a critique of the second, and focused on an alternative, post-carbon modernity based on renewables capable of providing adequate energy to modern societies without exposing them to either climate or nuclear risk. The fourth demand side ecomodernity focuses on demand side management and energy supply located close to the consumer. Concepts such as ‘energyplus’ houses and ‘smart grids’ are presented as alternatives to both carbon, nuclear and renewable based technologies supplied over the central grid.

Given the extensive infrastructure and institutional structures built up around electricity supply, the battle of carbon, nuclear and eco-modernities is a battle for the greening of Europe within different institutional co-ordinates: The carbon and nuclear modernities imply a continuation of the scale and scope economics of large centralized systems, though with a radical change of generation technology in the nuclear case. Supply side eco-modernity adds new resource bases with extensive re-location of electricity generation and raises new demands for balancing intermittent solar and wind supply. Demand side eco-modernity moves the focus out of the energy system and radically targets the consumer side where energy efficiency and self-supply become dominant concerns.

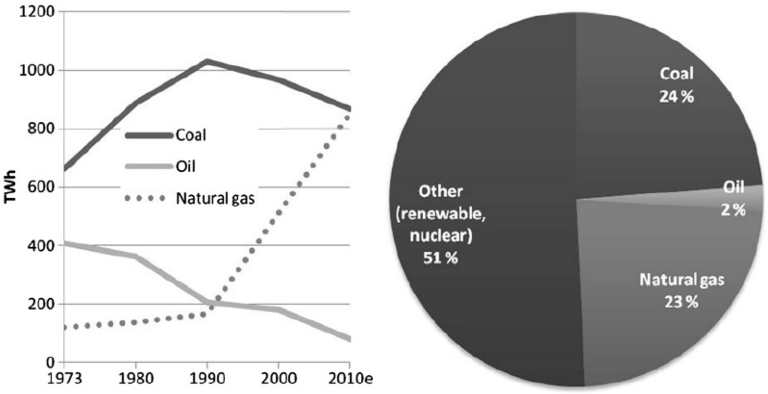
The paper draws on a vast number of secondary sources, ranging from research reports and articles to international energy statistics and policy documents, particularly from the European Commission. It also builds on information and reports from industrial associations and core European industrial actors. The main objective of the paper is to develop a holistic and synthetic conceptual framework for understanding the European electricity sector’s strategies to meet the climate challenge.

Carbon modernity

Carbon based electricity incumbents have met the climate challenge with a combination of incremental and radical, but system-conforming technological innovation and business strategies. They have basically followed a successful pattern from the 1970s and 1980s when they met the challenges of local pollution and acid rain with new filters and higher efficiency.

The most conventional approach has been to meet the climate challenge through efficiency improvements in coal-based generation technology designed to also bring down carbon emissions. It has also made attempts at combining coal with bio-fuels, as well as switching to gas with low CO2 emissions.

Fig. 3. Carbon modernity: generation by source 1973–2010.
Source: IEA (2011a).



A more radical, but still system-conforming strategy has been to move from coal to gas-based generation. Dominantly coal based incumbents in Western Europe see shifting from coal to ‘‘low carbon’’ gas turbines as a central part of its adaptation in the context of climate change. Gas has indeed increased its share of electricity generation dramatically over the last decades. While coal has lost market shares in the European electricity market, the gas strategy has been highly successful, allowing carbon modernity to more or less retain its position (Fig. 3).

In a more radical approach, carbon based electricity industry has sought to reinvent itself close to a zero-carbon solution. Carbon capture and storage (CCS), in which CO2 from power plants is captured at the plant and then transported and injected underground, is represented as the central gateway out of the climate squeeze for carbon-based electricity generation, making the use of fossil-fuel power plants virtually CO2-free.

Due to its political strength, the carbon based electricity industry has been able to mobilize extensive public funding into its climate-oriented innovation programs. Nevertheless, CCS technology at its present state incurs great efficiency losses and added costs that prevent large scale rollouts anytime soon.

The *political strength* and institutional backing of carbon modernity in confronting climate change is underlined by its ability to resist and strongly modify twomajor EU initiatives to deal with CO2 emissions from the carbon economy: the CO2/Energy tax and the European emissions trading scheme (EU Commission, 1997, 1999; Midttun and Koefoed, 2003). The European Commission’s proposal for a carbon tax, in the early 1990s was shot down by powerful procarbon lobbies in European heavy weight countries like Germany. Following the CO2 tax failure, the next and more successful European green policy initiative was the European emissions trading system (EU ETS). However, as the ETS allowed for decentralized adaptation, consisting of the allocation of allowances that took place at the member state level. Carbon interests could be weighted in by so called generous ‘grandfathering’ that gave large exemptions for existing generation capacity.

The *social legitimacy* of carbon modernity, in spite of the climate challenge, lies in the perception of carbon modernity as the basis for modernity as such. Throughout the 20th century electricity became a critical feature of modern life in mature western economies that citizens have not wanted to give up. However, faced with the carbon economy’s potentially devastating climate effects, they and are now left deeply split (Litvine and Wustenhagen, 2011). On the one hand they see the need for urgent climate action, well aware of the carbon bias of today’s electricity supply. On the other hand, electricity consumption in Europe has continued to grow, in spite of strong citizen recognition of the need for limitations to prevent climate change. Apparently, consumers expect to be able to retain modernity with all its benefits under a new climate-compatible regime. Hence the carbon incumbents have found public support for slow gradual and system compatible change rather than a dramatic exit out of carbon modernity.

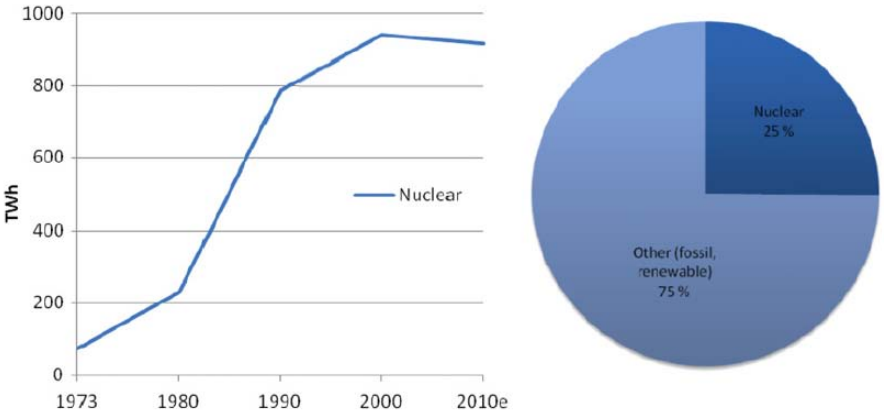
Nuclear modernity

The mainstream electricity industry in Europe would have met the climate challenge from a very different position if one of its most radical innovation projects – nuclear energy – had not seriously backfired. For the three decades following World War II, nuclear modernity was seen as a sustaining innovation beyond the carbon age, that retained many of the systemic characteristics of a central-station-based carbon modernity, while escaping from many of its vices. It was believed that nuclear power would render conventional power sources such as coal and oil obsolete, and that atomic energy would ‘‘provide the power needed to supply cheap energy for all’’.

Initial skepticism in the electricity industry was overcome by extensive support from public authorities through financial guarantees, massive research investments, and back-up from national military-industrial complexes. With the assurance of a prolonged transition period which would allow them to amortize their carbon investments, the incumbent electricity industry largely took nuclear power on board.

Nuclear modernity thus acquired public legitimacy as a successor to the carbon predecessor by upholding the modern lifestyle. From a commercial and technological perspective nuclear energy came to be seen as part of a high-tech nuclear industrial complex with attractive possibilities for industrial expansion and interesting and prestigious job opportunities. From a political point of view, nuclear technology was seen as a key to progress, and like carbon modernity, nuclear modernity was written into the constitution of the new Europe in the treaty of Rome in 1957.[2] Furthermore, nuclear electricity was seen to provide an answer to early environmental problems of the carbon economy such as smog and acid rain.

Fig. 4. Nuclear modernity: generation by source, 1973–2010.
Source: IEA (2011a).



Following a massive buildup of nuclear energy in several countries throughout the 1960s, 1970s and early 1980s, nuclear energy became a major force in Europe with an impressive 25% of electricity generated in the region (Fig. 4). In Belgium, France, Hungary, Lithuania and Slovakia it even became a leading electric power source (Wikipedia, 2011). The early boom for nuclear energy was matched by favorable public policies as the industry received the lion's share of the European research budgets as well as generous government guarantees to cover most of the costs from nuclear accidents over public budgets.

However, as nuclear industry expanded, the risks associated with it became more evident. Following a series of minor accidents and leaks throughout the 1960s and 1970s, nuclear power was faced with widespread public unease, coming to a head in the Three Mile Island accident in 1979, and the Chernobyl disaster in 1986. These accidents, led to massive civic protests in several countries, and nuclear modernity came to be associated with politically unacceptable risks. The public at large thereby joined the financial industry in seeing nuclear industry as too risky to be involved with. The first wave of nuclear power was

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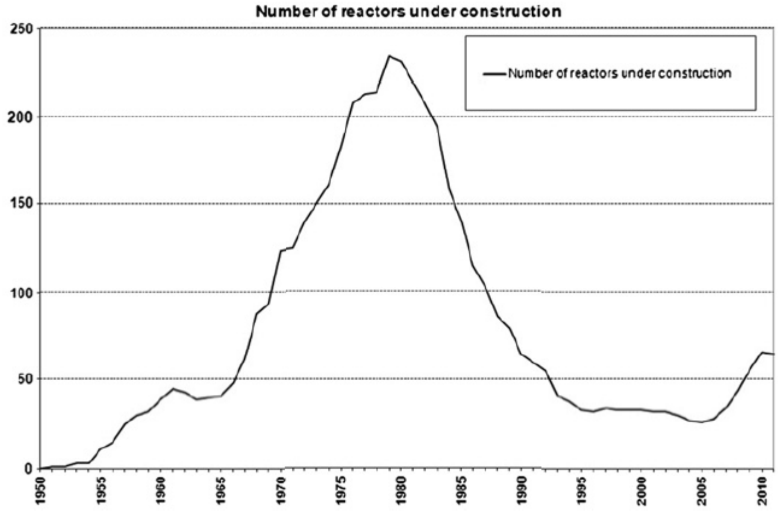
[2] The signatories to the Euratom treaty thus ''resolved to create the conditions required for the development of a powerful nuclear industry which will provide extensive supplies of energy, [and] lead to the modernization of technical processes…'' Euratom Treaty (1957).

thus stranded both in the USA and most of Europe, and new investments in nuclear capacity plummeted in the 1990s and early 2000s and nuclear power thus lost market shares (Fig. 5).

Fig. 5. Number of reactors (and total reactor capacity) under construction from 1951 to 2011. *Source*: IEA (2011b)



After more than 20 years without total nuclear accidents, nuclear modernity sought a comeback in Europe in the early 2000s, re-launching itself as a major solution to the climate challenge. Strong industrial actors, supported politically by a group of states, notably France, Finland and several East European member states, saw nuclear energy as the major driver of a postcarbon transition in the European Union. The sector was seen to represent a source of energy with low carbon levels and relatively stable costs, which made it attractive both from the point of view of security of supply and fighting climate change—two of Europe's major policy concerns.

Yet once again a serious nuclear accident – at the Fukushima plant in Japan – dramatically shook up the nuclear growth scenario. The accident in Japan once again challenged the nuclear lobby with a demonstration of nuclear risk that sparked public debate and triggered nuclear moratoria in several European countries, notably its biggest economy, Germany.[3]

Nuclear modernity remains thus highly ambivalent and contested as a climate strategy for the European electricity industry. Judging from the extensive delays and large cost-overruns for the latest European nuclear power stations, nuclear power also seems to be struggling with its economic competitiveness.

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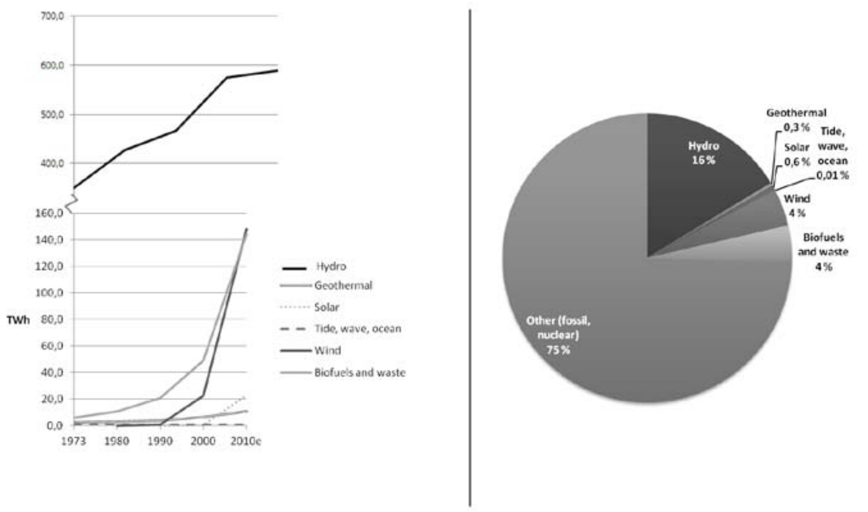
[3] The back-down from nuclear energy came after strong civic engagement. In March 2011, following the Fukushima accident, more than 200,000 people took part in anti-nuclear protests in four large German cities, on the eve of state elections and Chancellor Angela Merkel's coalition announced on May 30, 2011, that Germany's 17 nuclear power stations will be shut down by 2022.

Fig. 6. EU power capacity mix in 2000 and 2011. *Source*: IEA (2011a).



Supply side eco-modernity

Eco-modernity meets the climate challenge in an early phase of the product cycle. As opposed to the incumbent industry, ecomodernity is concerned with the climate challenge not as a secondary add-on, but as a primary raison d’ˆetre. In addition to confronting the challenge of greening, the challenge for ecomodernity is to provide a credible alternative to carbon or nuclear as the stable mainstream energy source capable of supplying the needs of modern society.

Initially, renewables were seen as marginal, unstable and unscalable sources of energy, too costly to compete with the incumbent coal and nuclear plants, and conflicting with the basic centralistic institutional and infrastructural design of carbon and nuclear modernities. Strong policy initiatives combined with active engagement from new entrepreneurial industrial players boosted growth in renewable energy throughout the 1990s and early 2000s. From a marginal add-on to carbon and nuclear modernity, renewables-based energy has grown into a major alternative in its own right.

The European electricity system featured extensive green transformation already after the first decade of the new millennium. With a larger share of installed capacity in renewables than in nuclear, green electricity is moving from niche positions to factors to be counted within mainstream supply, alongside largescale hydro (Fig. 6).

Hydropower

Although many of the renewable energy technologies are in the early stages of the product cycle, renewable energy also features hydropower, one of the most mature energy technologies. Hydropower has traditionally been the major source of renewable electricity, and accounts for approximately 16% of European electricity supply (IEA, 2011a). It has been central to electricity generation from the start in the late 19th century and therefore represents a familiar technology to mainstream industrial actors.[4]

However, much of the exploitable large scale hydropower has already been utilized, and remaining projects entail conflicts with other uses of water, such as irrigation, recreation and fisheries, as well as concomitant environmental and social stemming from dam construction inundation of large areas by reservoirs. These disadvantages now limit further exploitation of large-scale hydropower many places in Europe, and has forced a continuation of hydropower on a smaller and more socially acceptable scale[5], where projects are designed to blend in with nature and the landscape (Hydroworld. Com, 2011).[6]

While hydropower cannot play a major direct role in expanding green electricity, it may nevertheless play an important facilitating role as balancing power in response to the penetration of new intermittent renewable resources. The remarkably high Danish wind power share (more than 20% of total electricity supply) is thus effectively facilitated by using the Nordic hydropower system as a buffer. Attempts are also being made to broaden access to Nordic hydropower also in response to German and UK wind initiatives. Reservoir-based hydropower with efficient output regulation and capacity for storing large quantities of energy is thus acquiring an extended role as a green battery for one of Europe's most wind intensive regions. Similar use of Alpine hydropower reservoirs may play a major role in balancing intermittent renewable electricity supply in Europe.

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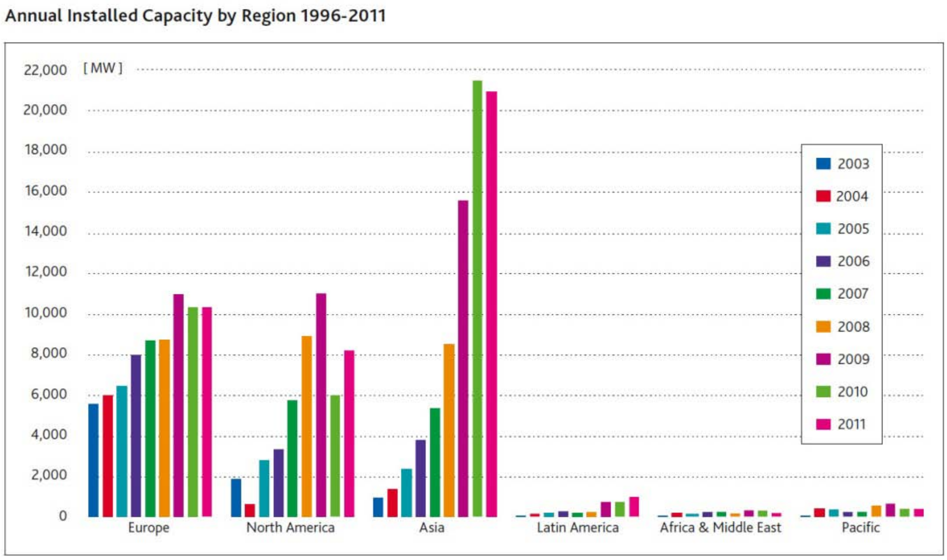
[4] Installed hydropower in Europe totals approximately 179,000 MW. European countries with the largest amounts of hydro include France, Italy, Norway, and Spain (Barnes, 2012). Estimated exploitable hydropower potential in Europe is 1670 TW h/a, but only 745 TW h/a were actually supplied by hydropower in 1990, and some 1080 TW h/a are expected to be available in 2020 (Lehner et al., 2012). Although there is a debate around methane emissions from hydropower reservoirs, in boreal reservoirs of Canada and Northern Europe, however, greenhouse gas emissions are typically only 2% to 8% of any kind of conventional fossil-fuel thermal generation (http://en.wikipedia.org/wiki/Hydroelectricity#Methane_emissions_.28from_reservoirs.29).

[5] Small hydropower is by no means new, and In 2006 there were nearly 23,000 small hydropower plants in the EU-27 including candidate countries Norway, Switzerland, Bosnia & Herzegovina and Montenegro, with an installed capacity more than 15,000 MW and a generation of nearly 52 TW h (European Renewable Energy Council). For small hydro (less than 10 MW), development opportunities are significant. Provided the mandate by EU member countries is implemented on a timely basis, the European Small Hydropower Association (ESHA) estimates that installed small hydro capacity could increase by more than 4000-MW over current levels (Hydroworld.com March 2011). http://www.hydroworld.com/index/display/article.

[6] The emphasis in Western Europe is to retrofit hydro plants with modern equipment, usually upgrading the capacity of the plant. In Eastern Europe, the focus is rehabilitating ageing plants that often were allowed to deteriorate during the era of the Soviet Union.

Fig. 7. Annual installed wind capacity by region. *Source*: Global Wind Energy Council (2011).



Wind

Over the last decade, Europe has seen a dramatic increase in wind power, indicating that it has entered the rapid growth phase of the product cycle (Fig. 7).[7] Spearheaded by an early Danish initiative in the 1980s, the region has become a technology leader and a lead market for wind. Denmark, did not only pioneer wind energy as an early starter, but also transcended the niche limitations and built up a world record wind supply amounting to more than 20% of total electricity consumption.

The pioneering Danish leadership is now followed by Germany which is the EU country with the largest installed capacity, followed by Spain, Italy, France and the UK (EWA—European Wind Energy Association, 2012). However, China is rapidly outpacing Europe in new capacity.

Following saturation of acceptable land sites and conflicts over land use in several European countries, wind power has expanded offshore. Once again, Europe has become a leading market with a growth of more than 50% during 2010. The U.K., followed by Denmark and the Netherlands are leading this development.

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[7] A total of 93,957 MW is now installed in the European Union, an increase of 11% over 2010.

Solar

Following ambitious policy initiatives, Europe has also made extensive advances in photovoltaic electricity.[8] With both centralized and local decentralized applications, solar energy has a valuable flexibility allowing it to adapt to diverse social and commercial needs. Growing contributions from Southern European countries are increasing the average load factor of this capacity and thereby enhancing solar energy's competitiveness.

In 2010, for the first time, Europe's photovoltaic sector installed more new capacity than any other renewable electricity source over the year (Photovoltaic Barometer, 2011). With over 80% of global installed capacity, Europe continues to be a leading market for photovoltaic installation (Fig. 8).

This development was mainly driven by three markets: Italy, Germany and France. The UK also delivered a surprising development during 2011. Other key markets in Europe were Belgium, Spain, Slovakia, and Greece (EPIA, 2011).

Biomass

Biomass, the fourth major source of green electricity has also expanded its market share significantly in the early 2000s although not as dramatically as wind and solar. Electricity production originating from biomass was 121 TWh in 2009 in the EU-27, with an average yearly increase of almost 13.5% between 2001 and 2009. Germany kept its role as the biggest bioelectricity producer, followed by Sweden and UK. These three countries represent almost half (48%) of the total production within the EU-27 Member States (Fig. 9) (Jäger-Waldau et al., 2011).

Following a critical debate on the use of agricultural land for energy crops, biomass based energy in Europe has concentrated on waste and forestry. Wood and wood waste remain the main source with a proportion of 53%, followed by municipal solid waste (28%) and biogas (19%) (Jager-Waldau et al., 2011).

The composition of bio-electricity, however varies from country to country. While Germany has developed a balanced bioelectricity production across all categories, the Nordic countries have achieved their leading position more exclusively through exploitation of their vast wood and wood waste resources. The UK, on the other hand has taken a leading position in biogas production.

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[8] The growth rate of PV during 2011 reached almost 70%, an outstanding level among all renewable technologies (EPIA, 2011).

Ocean power: Next generation renewables

While the first generation ‘‘new’’ renewables are now well on their way towards commercial viability, a second generation is making its early entry, and Europe is again taking a leading role. Most prominent in this generation is a series of ocean-based technologies, including wave, tidal (barrages and turbines), osmotic power, and ocean thermal energy conversion (OTEC) systems (REN21, 2011).

Fig. 8. Cumulative installed solar power.

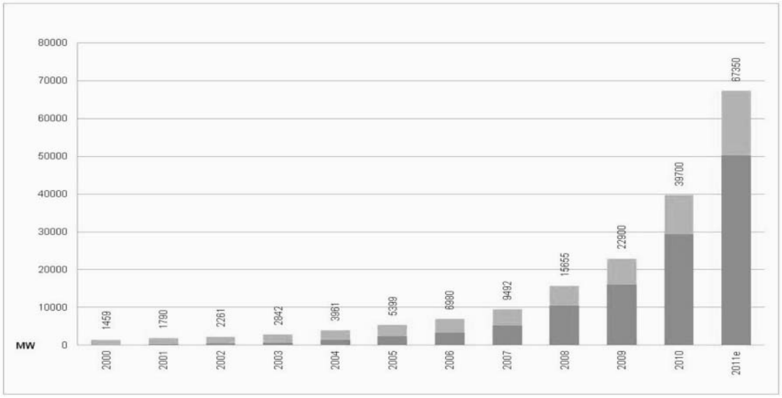
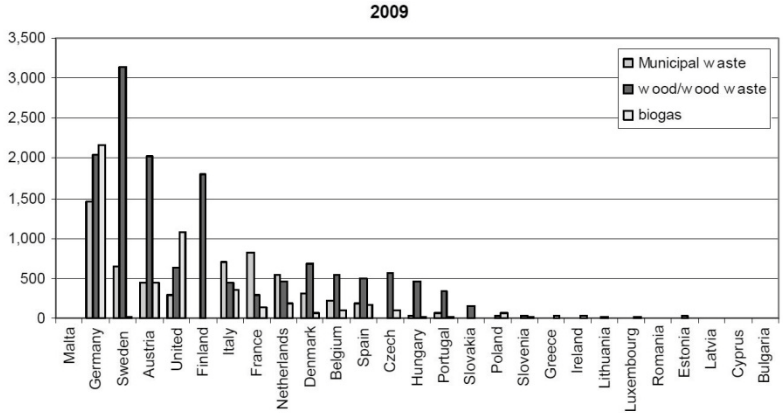


Fig. 9. Bioelectricity installed Capacity (MW) in the EU27 in 2009 by Categories. Source: Jäger-Waldau et al.: Renewable Energy Shapshots, 2011.



Though ocean energy technologies are not yet economically competitive with more mature renewable energy technologies such as wind, in the medium term these technologies could become significant contributors to markets in coastal states (European Ocean Energy Association, 2012). While the sector is 15–25 years behind wind energy, it is poised to follow a similar path to wider commercialization.

While limited to costal states, ocean energy has a vast potential. The worldwide wave energy contribution to the electricity market is estimated to be of the same order of magnitude as world electrical energy production capacity. Wave energy has the highest density among all renewable energy sources (European Ocean energy Association, 2012).

Europe is once again playing a leading role in green technology deployment. Many ocean power projects are already operative in Europe, with the majority operating off the coasts of Portugal and the United Kingdom for short-term testing and demonstration, and a few prototypes were initiating first steps.

One of the advantages of combining the new generation of ocean power with the previous generation of renewables nevertheless is that wave power production is much smoother and more consistent than wind or solar, resulting in higher overall capacity factors. As such it is attractive as a supplementary energy source.

The ability to trigger several generations of renewable technologies carries the promise of furnishing the continent with the emerging broad portfolio of technological options for a selfcontained eco-modernity in electricity provision.

Demand side eco-modernity

While carbon, nuclear and supply-side eco-modernities compete with alternatives of electricity generation, demand-side eco-modernity shifts the focus to the consumer and reduces dependency on centralized generation through efficiency improvement and self-generation.

It remains a paradox that while demand side eco-modernity is widely considered to contain some of the lowest hanging fruits in CO2 mitigation (von Weizs¨acker et al., 2009) (Fig. 10), it has been trailing behind supply side approaches both at the policy and industrial levels. This reflects established policy and industrial organization around centralized supply-side energy solutions.

EU energy policy is no exception. On the one hand the EU considers energy efficiency to be one of the most cost effective ways to enhance security of its energy supply and to reduce emissions of greenhouse gases and other pollutants. It has therefore set itself the target of saving 20% of its primary energy consumption compared to projections by 2020 (EU Commission, 2012). Yet, on the other hand, the EU is on track to achieve only half of the reductions as opposed to its far more successful policy implementation of green energy production.[9]

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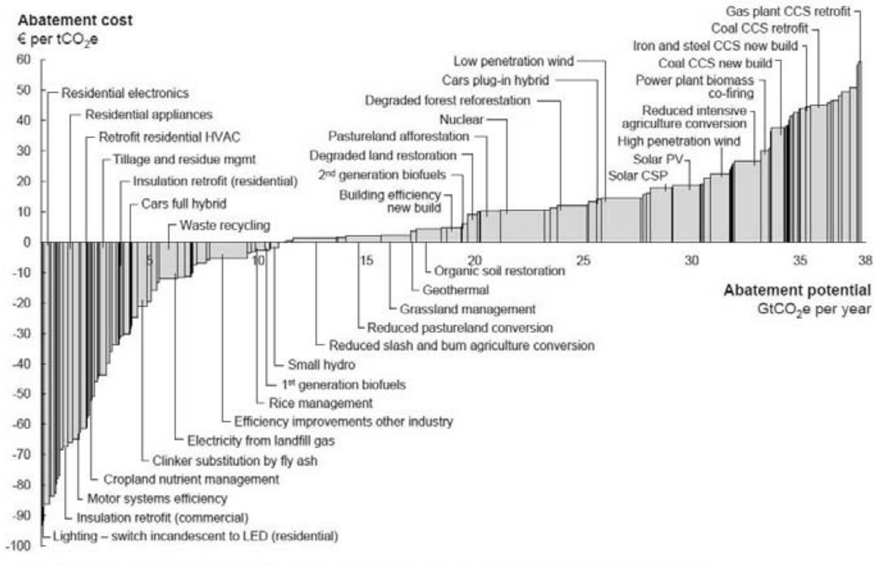
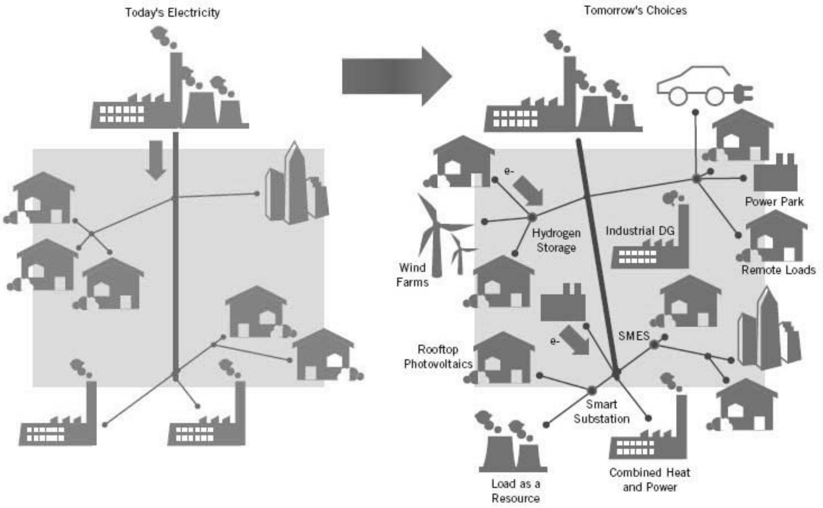
[9] Overall energy efficiency in the EU-27 has only improved by about 13% between 1996 and 2007 while EU households have only improved their energy efficiency. In households, energy efficiency improved by 1.1%/year since 1990 (Wikipedia, 2012).

Fig. 10. Overall cost-curve for energy efficiency options of end-use sectors in the EU27 in 2020. Energy savings are expressed in final energy units. *Source*: McKinsey (2009).



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.

Fig. 11. Smart grid. *Source*: IEEE, 2009



To reap the full potential of demand side eco-modernity there is a need to align policy, regulation, and public awareness in a broad range of fields, such as housing, transport, services and industry. Since policies are typically sectorally focused, crosscutting demand side eco-modernity is difficult to institutionalize.

To mention some examples, hurdles from the housing sector include principal-agent problems where the decision maker may be (partially) detached from the price signals. The most visible example is in rental markets, where building owners are responsible for investment decisions, but tenants pay the energy bills. In addition, policies that allow utilities to increase their profits by selling more electricity or natural gas are disincentives to effective utility energy efficiency programs. Many utilities also have applied tariffs and interconnection standards that discourage end users from adopting energy-efficient solutions.

Another hindrance is the often decentralized nature of the institutional competences in the building sector, with national, regional and local authorities playing different roles in enforcement, subsidy allocation, tax policy, etc. In the absence of proper coordination, this can easily result in sub-optimal support for energy efficiency in buildings (Directorate-general for energy (EU commission), 2012).

Nevertheless, the European Commission is now moving ahead with an energy efficiency directive (EU Commission, 2011b), and new demand-side initiatives are now being piloted in European nation states. Spearheaded by Germany and Scandinavia, Europe has staged a number of pioneering energy efficiency and selfgeneration projects in the housing sector, under the term ‘‘passive houses’’ or ‘‘zero energy buildings ‘‘or ‘‘energy plus buildings’’. Pioneering initiatives are also tapping into large energy efficiency and demand-side electricity production potentials in industry.

Demand side eco-modernity does not only involve decentralized demand-side management, but also means integrating demand- and supply-side measures in new ways. So-called ‘Smart Grid Initiatives’ are tapping into this potential via advanced information technology, thus optimally coordinating supply and demand (Fig. 11). Seen from the supply-side, smart grids enhance reliability, and reduce peak demand by shifting usage to off-peak hours. Seen from the demand-side, smart grids allow consumers to actively manage their local energy consumption and production up against the central generation system. In this way consumers may change positions as both net producers and consumers over time.

One decade into the 21st century demand-side eco-modernity remains at an early stage of achievement. There is a technological potential for reducing energy demand in space heating, hot water systems, appliances, indoor lighting and refrigeration with more than a factor 5, and there is a large technological and commercial potential for more dynamic optimization of demand and supply. Yet very little of this volume is targeted by effective political and commercial strategies, and the smart grid interface necessary to unleash these possibilities is still in the making. There are, however, signs of growth. To mention one example, the Italian electricity incumbent, Enel has been an early European front-runner, allowing Italian customers to view the information regarding their energy consumption thanks to electronic smart meters and remote management infrastructure.[10] A number of other companies have followed in Sweden, Finland and Denmark, and extensive rollouts of advanced metering infrastructure is planned in several of the larger EU member states, such as France, the U.K., and Spain (Greentechmedia, 2012).

In private housing and public buildings passive or positive energy housing involve a variety of techniques which both minimize energy use and maximize renewable energy generation in residential and commercial buildings. This includes energysaving modernization of buildings, ranging from refurbishing of windows, increased insulation and other energy efficiency measures. However, it also includes on-site active renewable energy technologies like photovoltaic to offset the building’s primary energy consumption and dispense with conventional heating systems.

With respect to industrial energy efficiency and self-generation, the International Energy Agency (IEA) estimates that spreading industrial best practices in sectors such as chemicals, iron and steel, cement, pulp and paper would imply energy savings of more than 30% (IEA, 2007). More radical examples can be found in the Swedish paper and pulp industry which, under the Swedish electricity certificate scheme has turned from a conventional large-scale consumer of electricity and fuel to an efficient producer based on waste bark, branches and wood chips (ABB Asea Browh Boweri, 2011).

Institutional facilitation

Europe’s leading role in climate policy and its strong initiatives for green transformation of electricity industry has been facilitated by three main factors: (1) Green civic and political radicalization stimulated by anti-nuclear protests; (2) Possibilities provided by a rich multilevel institutional structure, and (3) A broad set of policy instruments that have generated several technological routes. These factors have provided an institutional stimulus both to sustaining and disruptive transformation.

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[10] In the early 2000s Enel, installed 33 million smart meters through its Telegestore project, which is one of the largest and most widespread remote management infrastructure projects in the world and is a benchmark for all energy distribution companies (Enel, 2012).

Green radicalisation

At the political level green radicalization, in particular in Europe's Northwestern fringe, opened up a broad eco-modernity agenda alongside the carbon and nuclear incumbents. Antinuclear civic action, that spiked after the Three Mile Island and Chernobyl accidents, merged with broad green parties that gained political influence through political alliances, and both stimulated and facilitated eco-modernity.

The nuclear opposition in several European countries grew steadily more radical through clashes with established pronuclear elites over nuclear installations, and the confrontations provoked by the Three Mile Island and the Chernobyl nuclear accidents. Ultimately this brought down the program of nuclear modernity in several European countries and boosted the ‘‘green opposition’’ with visions of an alternative renewable energy future.

The emergence of green opposition took various forms across Europe. In Sweden the anti-nuclear opposition was able to mobilize a nuclear referendum already in 1980, the year after Three Mile Island, leading to a moratorium on nuclear energy in Sweden. Out of the nuclear opposition movement grew a green party referred to in Sweden as simply *Miljöpartiet*: ‘The Environmental Party’. It won seats in the of Swedish Parliament for the first time in 1988, failed to pass the 4% cutoff in the following election in 1991, but returned again in 1994 and has held seats since, getting around 5% in every election. In the election in 2010 they got 7.34%, making them the third biggest party in Sweden.

The nuclear crises also boosted the green opposition in Denmark, which gradually merged with the left wing party and the people's socialist party. Driven by the green visions, Denmark rejected nuclear option and even legislated a prohibition against nuclear energy in 1988, following the Chernobyl nuclear disaster. Instead, the country embarked on an alternative ecological modernity, spearheaded by an ambitious wind-energy program.

Germany has been a battleground of the nuclear and eco modernities. With its strong industrial basis, the country has aspired to be a nuclear technology leader, but it also sees the rise of a persistent opposition which has extensive mobilizing power. Since the early clashes over location of nuclear plants outside the village of Wyhl in 1971, Germany has been engaged in hefty nuclear battles, including clashes over the Brokdorf reactor on the North Sea coast, the fast breeder reactor at Kalkar in the lower Rhine region and many others. The Three Mile Island accident in the US fostered large demonstrations against a reprocessing plant in Gorleben, and this stimulated the German Green Party, which became one of the most influential forces of green politics in Europe. They were founded in 1980 and have been in coalition governments at state level for some years. At the federal level, the green party held government with the Social Democratic Party of Germany in a so-called Red-Green Alliance from 1998 to 2005 during which a Germany took several initiatives to boos ecomodernity. In 2001, this government also reached an agreement on nuclear power in Germany, and thus formally halted the expansion of nuclear modernity.

Multilevel institutional pluralism

The interpenetration of alternative modernities has also profited from the rich web of national diversity, multilevel decisionmaking and institutional pluralism in Europe, which has limited the power incumbency and created multiple entry points for climate-oriented entrepreneurship. While national subsidiarity has created multiple spaces for specialized entrepreneurship and innovation, the wider European market has facilitated learning and adaptation across boundaries.

Institutional pluralism and national diversity

Institutional pluralism and multilevel decision-making is in part embodied in the European Union's open method of coordination that encourages specific flexible and negotiated solutions. While a common set of norms is implemented in all member states, they are allowed to pursue them scaled to the level of national capacity, and with a variety of technologies and policy means. The European construction with common over-arching goals, but with generous subsidiarity in policy implementation, has thus opened up for extensive national diversity and even rivalry. Different European nations have promoted new technologies where they have seen the greatest industrial potential. Sweden and Finland have launched forestry-based biofuels, Germany and Spain photovoltaics, Denmark, followed by Germany and Spain—wind, and the UK taking initiatives in offshore wind and early stage ocean technologies. This has not prevented France from strong engagement in favor of the nuclear climate solution. However, by letting national diversity play itself out on the common European arena, the EU avoids a majoritarian lock in to incumbent energy technologies and opens up for competing modernities. The national rivalry for the exploration of alternative green technologies has in part been driven by green policy-visions which followed the rise of green political mobilization, and by aspirations of technology leadership under anticipated green growth.

In addition to facilitating national climate initiatives, the EU itself has stimulated both eco-modernity and carbon based climate innovation by setting ambitious overarching climate targets which have served to speed up implementation throughout the region. As opposed to national targets that may be nationally renegotiated, EU-level binding targets provide obligations for countries under threat of EU sanctions.[11]

Interfaces with market de-regulation

The EU has also facilitated a new commercial dynamic space for commercially based climate initiatives through its extensive de-regulation of European energy markets. Energy businesses have re-configured strategically to meet new market opportunities and are increasingly seeing eco-modernity as part of their strategic agenda. Green policy initiatives have also created market- stimuli that support green commercial engagement in ecomodernity on par with carbon- and nuclear engagements. In response, the green industrial segment is rapidly increasing volume and gradually strengthening its voice in industrial policy, alongside carbon and nuclear incumbents on the European electricity scene.

A relay model

The European success in pioneering transition towards climate-sustainability resembles, in many ways, a relay race, where various factors have driven innovation at different stages. At one point change may be politically driven, while at another point the baton is taken by markets, technology or civic mobilization. Causality may therefore change as in a relay run, across politics, markets, technology and civic engagement. In addition, chance events may transform the contest.

The logic of the relay process can be described in terms of an open game tree, where each step elicits blockage or further policy evolution in the same direction as the sequential triggering takes place (Midttun, Anne Louise 2003) (Fig. 12). While strong policies may easily lead to blockage, softer and less confrontational policies with triggering effects in other institutional domains may have better chance of success. The sequential triggering may build momentum behind green policies and move towards a *de facto* stronger green effect.

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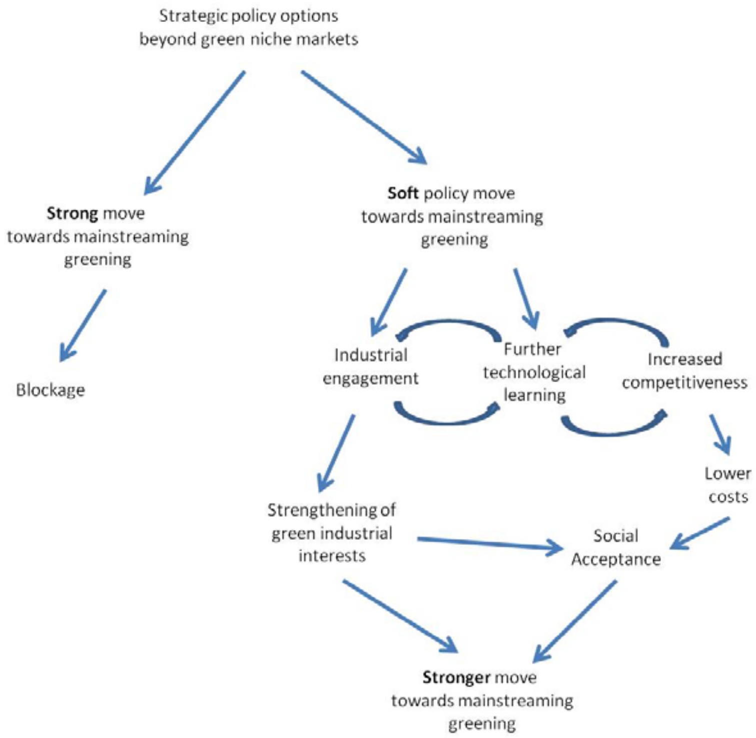
[11] The targets have been carefully negotiated under consideration of specific natural resource conditions and national economic and industrial capabilities, ranging from 10% in Malta to over 50% in Sweden.

Fig. 12. The relay model in open game form



There are examples where too-bold projects have stranded or backfired. Green initiatives to shift taxation from work to pollution and environmental degradation were effectively undermined by strong industrial lobbies. The European Commission's proposal for a carbon tax in the early 1990s was thus shot down by powerful pro-carbon lobbies in European heavy weight countries like Germany.

The launch of a European emissions trading system (EU ETS) was more successful. It was introduced more carefully and effectively softened through lavish allocation of allowances and generous ‘‘grandfathering’’ that gave large exemptions to existing generation capacity. Nevertheless the battle over principles has been won by eco-modernity, and the ETS may later be recalibrated to become more effective.

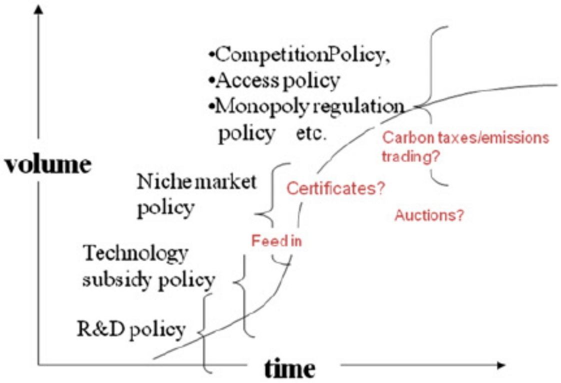
Another successful step has been taken with the establishment of direct stimuli to green technologies through ambitious feed-in tariffs. By creating a green niche market alongside the regular electricity market, the policy initiative did not directly confront incumbent industry, and although it was first opposed by incumbent industry in European court, the green niche market has come to be accepted.

A broad set of facilitating policy instruments

Out of the European institutional pluralism and the national contest for green technological leadership there has emerged a broad set of policy instruments, capable of supporting technology development at various stages of maturity in the product cycle (Fig. 13):

- Feed-in tariffs have driven the whole host of technologies with tailor-made tariffs for individual technologies to trigger learning processes through early technology deployment.
- Certificate models with renewable obligations and competitive pricing have stimulated the more mature technologies: particularly bio-based electricity generation from forest waste in Scandinavia.
- The European emission trading system has provided an implicit taxation on carbon that has benefitted most mature technologies.

Fig. 13. Policy instruments in the product cycle.



A monolithic CO2 taxation and emissions trading approach would have failed to drive new immature technologies that are still too costly to be favoured by any realistic CO2 taxation.[12] With only emissions trading and/or carbon taxation, climate policy would risk getting stuck in the middle, where realistic levels of CO2 taxation are not sufficient to drive the new technologies to replace the current carbon economy, but are still painful enough to slow down growth and trigger opposition.

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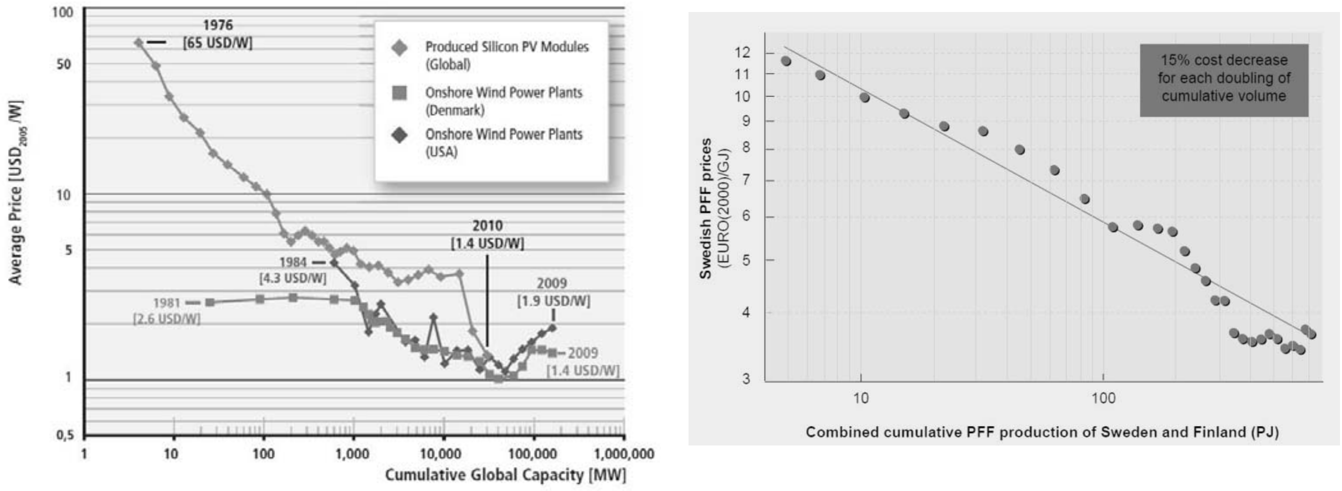
[12] The EU ETS has seen carbon prices in high periods close to EUR 20/t and in low periods down below EUR 10/t. This translates into price uplifts on electricity between 10 and 20%, and is clearly insufficient to drive new immature energy technologies.

By providing much higher, but focused support for deployment of small volumes of new green technologies through feed-in tariffs, a number of European policy-makers have driven technological learning at affordable costs. Through imposing a minimal tax on electricity consumption, the broad ‘‘tax base’’ of the total electricity consumption have provided financing for the initial high payments to small volumes of renewables necessary, without seriously affecting the electricity price. At intermediate stages of maturity auctions and certificate markets have stimulated technology development further.

Fig. 14. (a) Learning curves for wind and photovoltaics. *Source*: IPCC – SRRN (2011). (b) Forest residues in Sweden and Finland. *Note:* PFF¼Primary forest fuel. Source: Faaij et al. (2005).



The diversity of European policies, catering for different stages of the product cycle, has allowed for multiple technologies to emerge. They represent several modernities which coexist side by side with one another. The sum of the European technology deployment policies has been central to dramatic technological performance improvements in renewables. The story of European technology deployment for the maturing of renewables like wind, photovoltaics and biomass-based electricity, is a story of remarkable technological success. Strong feed-in policies have brought industrial prototypes into dynamic learning processes, where costs have been driven down by several orders of magnitude over only a few years. This has resulted in rapid expansion and industrial learning. The cost evolution of wind and photovoltaics illustrates this progress (Fig. 14a). For both of these technologies, support policies and certificate-based niche markets have successfully driven costs down towards competitiveness with incumbent technologies. Similar learning has also taken place in bio-energy (Fig. 14b).

Following successful technology development, Europe faces a need to step up market pressure. Explosion in feed-in payments in Spain and partly Germany in response to rapid expansion of renewables, forced shutdown of subsidies or a transition to adynamic feed-in, where the rates had to be constantly lowered to prevent windfall profits for new and more cost efficient production. As new technologies have matured under feed-in tariffs, they could also transit to certificate and obligations markets and finally to compete with incumbent carbon technologies under CO2 emissions pricing.

Is the battle about to be won?

After major successful breakthroughs for several renewables, is the battle of modernities about to be won?

Clearly Eco-modernity has produced two winning technologies: wind and solar. With formidable growth rates ranging from 25 to 50%, the two technologies are positioned to grow extensively. Having increased cost-efficiency dramatically over the past decade, these technologies are also approaching commercial competitiveness. However, wind in particular struggles with an intermittency problem that entails a need for complementary stabilizing technology. Furthermore, competing land use and esthetic consideration pushes wind to more costly offshore sites. Similarly, solar power is challenged by land use issues for centralized applications while its decentralized applications are challenged on esthetic grounds. Despite obvious successes, ecomodernity still has serious hurdles to overcome.

The incumbent carbon and nuclear modernities have had the advantage of meeting the climate challenge with the strength of established positions and resource control. They have organizational and commercial resources of the large firm with strong market positions, including lucrative control over balancing markets. Furthermore, they enjoy a tailor-made grid infrastructure developed to support their central station design. From this position the carbon incumbents have successfully met the climate challenge with natural gas. With a formidable growth of more than 400% over the last couple of decades, it is the major growth sector in European electricity generation. The problem is, however, that gas can only be a transitory solution. It represents a major reduction of CO2 emissions compared to coal, but is incapable of responding to a more ambitious CO2 reduction policy towards EU ambitions for 2050. Efficiency improvements in coaland gas-based technologies can only add marginally to this.

The engagement in CCS to deliver a more fundamental transition to close-to-zero emissions has come late and has not yet made a convincing breakthrough in cost-reduction and efficiency. CCS technology at its present state incurs great efficiency losses and added costs which prevent large scale rollout anytime soon. Furthermore, CCS also suffers from lack of social acceptance, which has spilled over to political refusal to designate underground storage in several German Länder. Both technological setbacks and social legitimacy remain therefore serious hindrances to meeting the climate challenge within the carbon modernity paradigm.

Similarly, nuclear modernity – the incumbent industry's most radical answer to the climate challenge – has failed to achieve civic or social legitimacy. It took 20 years to move towards a revival after Chernobyl. The Fukushima accident re-activated fear and once again reminded the public in western democracies of their distrust of nuclear safety. It does not make the situation any better that nuclear industry after half a century of operation has failed to find long-term storage for nuclear waste that is acceptable to the public. Furthermore, the stop-go character of nuclear development has affected its economic performance. Against this background, radical greening of European electricity through nuclear modernity remains highly questionable and is explicitly off the agenda in several influential West European countries, such as Germany, Sweden, Austria and Switzerland.

As we have observed, demand-side eco-modernity is still lagging behind. As opposed to CCS, the problem is not primarily technological, but mainly institutional. Further unleashing of demand-side potentials may need re-regulation of deregulation, where the commercial efficiency of deregulated energy markets is taken further into removal of barriers to energy efficiency in the interface between electricity and other sectors. Flexible interplay between electricity markets and various off-grid and energy efficiency measures needs to be guaranteed and supported. Reduction of institutional barriers to resource-efficiency is needed to tap into the huge demand-side potentials.

To sum up, carbon modernity has come up with a viable midtermsolution – gas – but failed to generate a credible long term response. Promising accelerated growth in wind and photovoltaics raises hopes for a substantive contribution from eco-modernity, yet exploiting its full potential will need mainstreaming and institutional alignment. Demand-side eco-modernity – being a disruptive innovation – remains a challenging vision, and will need institutional transformation.

Europe’s way forward

Following its early leading renewable energy initiatives, Europe continues to flag advanced ambitions: In the aftermath of the publication of a number of other low carbon visions, the European Commission in December 2011, launched the ‘‘Energy Roadmap 2050”. The roadmap commits the EU to reducing greenhouse gas emissions to 80–95% below 1990 levels by 2050, depending on necessary reductions by other developed countries.

A pre-condition for sustained successful climate leadership is for Europe to continue to move on several modernity-frontiers. Building on European diversity in resources, competencies and political preferences, the Continent has produced an interesting variety of climate approaches.

Demand-side eco-modernity continues to be a challenging project. While battles obviously are being fought between the carbon incumbents and supply-side eco-modernity, an even more fundamental fissure remains between supply-side and demandside solutions. Tapping seriously into this modernity becomes an important prerequisite for EU’s ambitious plans.

In the context of current financial and economic crises, growth and employment become paramount. A strong motivation behind European renewables stimulation policies has been to launch green growth. As a result of Europe’s early engagement and role as a lead market, the continent has fostered some of the major wind turbine and photovoltaic module manufacturers. With a business model built on outsourcing and rapid technology-transfers, however, technology monopoly is not retained over a long time. The expanding US and Asian markets are providing major roles for non-European players.

While the Danish wind pioneer, Vestas, holding 14.8% of the global market for wind turbines, retained a leading position in 2010, a Chinese company has advanced to the second position, followed by US and Chinese firms. Leading German and Spanish players trail behind with market shares around 6–7%, but they are challenged by the Indians and the Chinese in the same marketshare range (Table 1a).

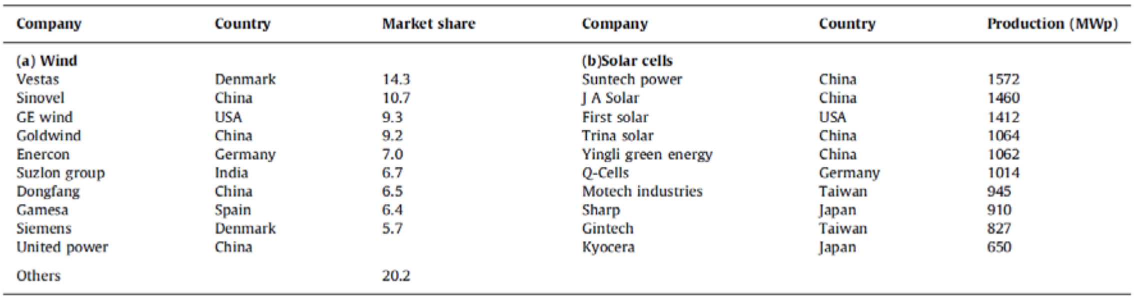
In photovoltaics Chinese and Taiwanese firms have held six of the ten slots including the top two (Photovoltaic Barometer, 2011) (Table 1b). This development has unfolded rapidly and Chinese firms, in 2010, had more than 50% of the global photovoltaic module production, against less than 15% in 2006.

However, the massive growth of the European market for renewable energy entails many European jobs. A large part of the value of wind, as well as photovoltaic systems is created further downstream and closer to the consumers and generates European business and jobs. Furthermore, while European firms have lost market shares, the relative over-capacity, especially in photovoltaics, following the rapid scale-up of Asian production, has reduced module prices further and thus triggered expansion of eco-modernity.

Furthermore, the price-hike on energy and other resources obviously motivates engagement in freely available renewables. As indicated by Fig. 15, critical energy resources are becoming increasingly scarcer and more expensive and thus drive prices up dramatically in global markets. As one of the most carbon-import dependent regions, Europe may have motivation to stay on the green course.

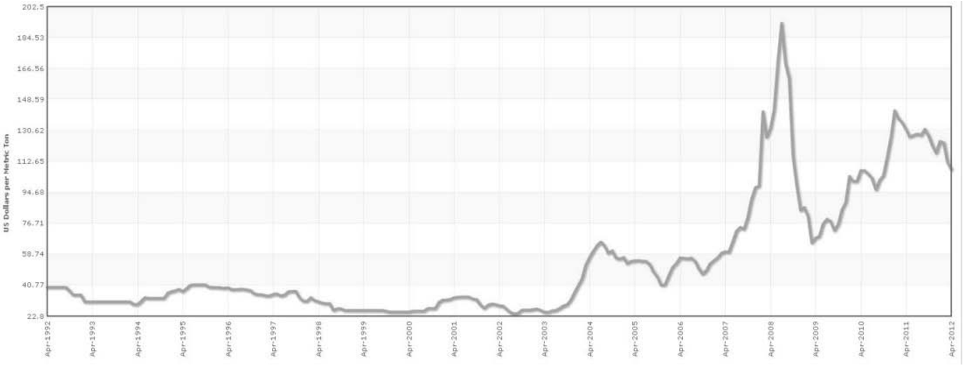
The lesson from the European experience is that transitions across modernities necessitate engagement with a broad spectrum of policy tools: commercial, political, technological and communicative. Our analysis also highlights the importance of well calibrated policy initiatives and awareness of their interaction with other realms. Europe, in this respect, has the advantage of an institutional pluralism residing in the complex European political mosaic. The same pluralism, however, challenges scalability, as solutions need to be mainstreamed into dominant solutions. If Europe is to succeed in following its past lead market initiatives and living up to its pioneering visions for a close to carbon-free electricity market in 2050, it needs to cleverly manage this balance.

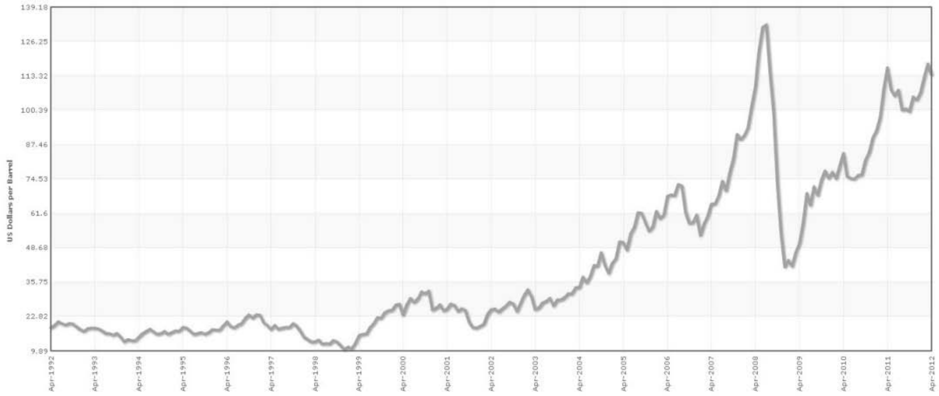
Table 1: Top wind and solar cell producers globally. *Sources*: Wind: Renewables 2011—global status report; Solar: Photovoltaic Barometer no 5, 2011.

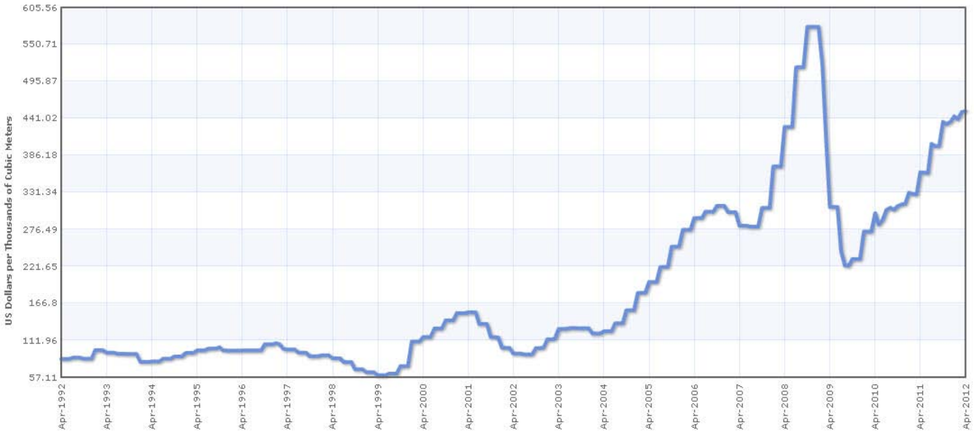


Company	Country	Market share	Company	Country	Production (MWp)
(a) Wind			**(b)Solar cells**		
Vestas	Denmark	14.3	Suntech power	China	1572
Sinovel	China	10.7	J A Solar	China	1460
GE wind	USA	9.3	First solar	USA	1412
Goldwind	China	9.2	Trina solar	China	1064
Enercon	Germany	7.0	Yingli green energy	China	1062
Suzlon group	India	6.7	Q-Cells	Germany	1014
Dongfang	China	6.5	Motech industries	Taiwan	945
Gamesa	Spain	6.4	Sharp	Japan	910
Siemens	Denmark	5.7	Gintech	Taiwan	827
United power	China		Kyocera	Japan	650
Others		20.2			

Fig. 15. Energy prices scaling-up. *Source*: Index Mundi







The EU has, over the last couple of decades, through dynamic stimulus policies, provided lead markets for core renewable technologies such as wind and solar. Impressive performance improvements and growth rates indicate that they are now approaching commercial viability. The starting point for the next phase of the relay run is a maturing green electricity industry with considerable influence and potential job creation. Europe therefore seems to be coming close to a green tipping point also with respect to institutional power, as indicated in the EU’s ambitious 2050 roadmap. Three hurdles need to be overcome, however: (1) accommodation of the new East and Central European ‘‘catch-up’’ economies still very much embedded in carbon modernity; (2) tackling of green industrial ‘‘leakage’’ to Asia; and (3) institutional inertia in demand-side ecomodernization.

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