The Greening of European Electricity Industry: A Battle of Modernities

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Introduction

Europe has played the role of a green hegemon on the global arena for several decades. Europeans were front runners in launching the United Nations Framework Convention on Climate Change in Rio in 1992. The European Union pioneered the follow-up 1997 Kyoto Protocol with binding reduction targets. It fought for a follow-up in Copenhagen in 2010. The question is however, whether it is on track with regard to delivering at home. While the EU has set ambitious targets for becoming a green economy in its “Roadmap for moving to a low-carbon economy in 2050” it still has a long way to go.

This paper explores Europe’s achievements and challenges with regard to meeting the climate challenge and pioneering green transition in the electricity industry, a major CO2 emitter in a modern industrial economy. Our study is published while Europe’s green transition is still very much in the making. It therefore provides an early stage assessment and an outlook for the future unfolding of the greening Europe.

We argue that the greening of Europe is not a unified process. On the contrary it is a highly dynamic development and can be best represented in terms of competing modernities. Further we wish to contend that the European success in pioneering transition towards climate-sustainability lies in an approach that resembles 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 mobilisation. While strong policies may easily lead to blockage, softer and less confrontational policies with triggering effect in other institutional domains may have better chance of success.

The sectoral approach provides a focus that allows a closer analysis of strategies, policies, and public engagements. Both markets, regulatory approaches and industrial strategies tend to be sectoral and public engagement also typically focuses on sector-specific issues. Given the interest in not only exploring patterns of electricity generation and CO2 emissions, but also drivers and processes behind them, a sectoral approach is more or less a must.

Transformation of Large Socio-Technical Systems

In a mature economy, such as the West-European, 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 a 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 supprotive rules and regulation (a socio-technical system) (Hughes....). 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 socio-technical system can be illustrated in terms of a standard product cycle model with an institutional dimension added on (figure 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”).

Figure 1
Illustration of the implications of institutional lag.

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 disalignment 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 figure 3, 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 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.

Figure 2: Conforming and Disruptive Transformation

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 non-polluting energy-abundance. The third eco-modernity 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 neither to climate or nuclear risk. The fourth demand side eco-modernity focuses on demand side management and energy supply located close to the consumer. Concepts such as energy plus houses and smart grids are presented as alternatives to both carbon-, nuclear and renewable based technologies supplied over the central grid.

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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.
Given the extensive infrastructure and institutional structures built up around electricity supply, the battle of carbon, nuclear and eco-modernities is a battle for 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-modernitiy 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**

Since the industrial revolution carbon modernity came to be associated with modernity as such. As large central, state-of-the-art generating stations, located nearer fuel supplies and connected to high-voltage transmission lines, became the dominant industrial pattern, carbon modernity was capable of providing cheap energy, while improving reliability and the use of resources. On this basis, European consumers have massively bought in to impressive welfare-benefits from a wide array of electricity based home appliances ranging from washing machines to mobile phones, from fridges to computers.

Coal based electricity generators successfully adapted to stronger environmental expectations in the 1970s and 1980s and met the challenge of local pollution and acid rain with new filters and higher efficiency, without upsetting electricity consumption in any way. Consumers basically expect the electricity system to deliver similarly on the climate challenge, and to transit as smoothly to a low-CO2 future while retaining all the benefits of modernity.

Against this background, carbon based electricity incumbents have met the climate challenge with a combination of incremental and radical, but system-conforming technological innovation and business strategies.

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. The Polish energy group Tauron Polska Energia (2012), illustrates the efficiency approach, as it continues to strive for efficiency improvements in new coal plants, now justified by lower carbon emissions in addition to traditional economic efficiency arguments.
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, like energy conglomerate RWE, see shifting from coal to “low carbon” gas turbines as a central part of its climate adaptation. 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 (figure 3).

**Figure 3: Carbon Modernity: Generation by Source 1973 – 2010**

![Graph showing carbon modernity generation by source 1973-2010](Source: IEA (2011))

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 the CO2 from power plants is captured at the plant and then transported and injected underground is launched 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. The German incumbent E.ON may serve as an example. In 2010 it proclaimed that by 2030 it expected that all its power plans would include CCS, and actively engaged in CCS projects to support this development. Given its political strength, carbon based electricity industry has been able to mobilize extensive public funding into its climate-oriented innovation programmes. Nevertheless, CCS technology at its present state incurs great efficiency losses and added costs that prevents large scale rollout 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 two major EU initiatives to deal with CO2 emissions from the carbon economy: the CO2 /Energy tax and the European emissions trading...

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2 ... Gas-fired power stations are the single most important item in our power plant investment package in terms of both the number of projects and their total capacity. With an efficiency of up to 60%, Combined-cycle gas turbine power stations (CCGT) plant are the most efficient of all fossil-fuel power stations ... http://www.rwe.com/web/cms/en/108460/rwe/search/?a=YqJ2Chhr6hAzYGck76P%2FhUQVIdteB5wVC3v1iUapcA%3D
scheme (European Commission 1997; European Commission 1999; Midttun & Koefoed 2003). The European Commissions proposal for a carbon tax, in the early 1990s was shot down by powerful pro-carbon 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 decentralised adaptation, the allocation of allowances took place at the member state level, the carbon interests could be weighted in by so called generous “grandfathering” that gave large exemptions for existing generation capacity. The incentives to move the economy out of carbon were therefore limited and supportive of the incumbents’ pledge for slow gradual transition.

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 do not want to give up. However, faced with the carbon economy’s potentially devastating climate effects, they and are now left deeply split: 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 dramatic exit out of carbon modernity.

Nuclear Modernity

Mainstream electricity industry in Europe would have met the climate change from a very different position if one of its most radical innovation projects – nuclear energy – had not seriously backfired. For the three decades following the II World War, 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 electricity industry was overcome through 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 modern lifestyle. From a commercial and technological perspective nuclear energy came to be seen as part of high-tech nuclear industrial complex with attractive possibilities for industrial expansion and interesting 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\(^3\). Furthermore, nuclear electricity was seen to provide an answer to early environmental problems of the carbon economy such as smog and acid rain.

Following a massive buildup of nuclear energy in several countries throughout the 1960s, 70s and early 80s, nuclear energy became a major force in Europe with an impressive 25% of electricity generated in the region (Figure 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 nuclear industry received its lion’s share of European research budgets as well as generous government guarantees to cover most of the costs from nuclear accidents over public budgets.

![Figure 4: Nuclear Modernity: Generation by Source 1973 – 2010](source: IEA (2011))

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 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 has lost market shares (figure 5).

\(^3\) The signatories to the Euratom treaty\(^3\) thus “resolved to create the conditions required for the development of a powerful nuclear industry which will provide extensive supplies of energy, lead to the modernisation of technical processes...”
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 post-carbon 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.

Its proponents also argued that nuclear technology has made advances that now extensively diminished its risks and that these risks were necessary to take as we face the perils of global warming. Several of the nuclear-supporting states engaged in construction of new nuclear capacity. Countries with nuclear moratoria, such as Germany and Sweden were also on a gliding path towards nuclear acceptance, setting out to prolong the life of existing nuclear plants through upgrading.

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.

At the industrial level, The French EDF group has continued to figure as a nuclear front-runner. Heading the nuclear revival to meet the climate challenge, the group focused on being a major player in the global nuclear revival, while promoting energy efficiency, renewable energies, more environmentally-friendly new technologies as supplementary side-concerns. Following the

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4 The backdown 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.

5 This strategy emerged out of a gradual development where EDF in its 2006 annual report stressed its ability to be a leader in the post-oil era. The focus on climate became more explicit in 2007 with formulations like: the “urgency of climate
Fukushima catastrophe the nuclear rhetoric was toned down somewhat and focus on safety indicated by the heading “Safety: our number one priority” (EDF 2011a).

Besides EDF, The Finnish TVO group and the Czech CEZ group have been ardent nuclear supporters: The TVO group, owned by Finnish paper and pulp industry (Through PVO) and the Finnish State (through Fortum) engaged in building additional nuclear capacity, motivated by securing energy supply at relatively low prices, diminishing greenhouse gas emissions (EDF-Business 2011b). The Czech CEZ group – a major Central and Eastern European energy player, has also seen nuclear energy as a strategy going forward. The background for strong nuclear engagement in the Czech Republic is, like in Finland, concern with security of supply.

Other integrated carbon and nuclear based electricity companies, such as EON, reflect the policy-diversity of their national contexts. In Germany the company accepts the decision by Germany’s political majority to accelerate the phase-out of nuclear power. In the UK, on the other hand, EON is playing a leading role in developing the next generation of new nuclear power stations. In a joint venture with RWE npower called Horizon Nuclear Power, EON UK, thus, works to develop new nuclear power stations in the UK (EON-UK 2011).

Nuclear modernity, remains thus highly ambivalent and contested as a climate strategy for 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.

**Supply Side Eco-Modernity**

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

Initially, renewables were seen as marginal, unstable and un-scalable source of energy supply, 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 ecological modernity in its own right.

*change became clear for all*. EDF here flagged its intention to “play an active role in the nuclear revival of the world’s leading energy markets”, in addition to being “a leader in the field of renewable power. 2011 webpage (10 April 2011)
Europe has emerged as a front-runner in several core renewable technologies due to a combination of technology competencies and a successful development of policy tools capable of driving technological development and its commercial exploitation. The feed-in policy acquired legitimacy from the nuclear protest, and from civic alignment around green policies in core European countries.

Rivalry between various national policy designs has created a plurality of approaches representing technology development at various stages of maturity. So called feed in tariffs have driven a whole host of technologies with tailor-made tariffs for individual technologies to trigger learning processes through technology deployment. The tariffs have been supplemented with feed-in rights to prevent entry barriers from incumbent market players. The rapid technological learning forced a transition to dynamic feed in, where the rates had to be constantly lowered to prevent windfall profits for new and more cost efficient production. Certificate models with renewable obligations and competitive pricing have stimulated the most mature technologies: particularly bio-based electricity generation from forest waste in Scandinavia. As new technologies mature under feed-in tariffs they may also transit to certificate and obligations markets.

The strong policy-engagement has been driven by green visions, but also by aspirations to technology leadership under coming green growth. Furthermore, the combination of feed in with technology learning and driving the learning curves also raised the promise of technological leadership in a coming market. Denmark early on acquired a leading market-position in wind turbines, and Germany, with its broad industrial and technological expertise envisaged to replicate this experience in a broader spectrum of green technologies. Out of this has emerged a vibrant European renewable energy industry.

The European Union has also been instrumental in promoting green electricity. The EU Renewable energy plans and the renewable directive (EC 2009) has set an ambitious overarching obligation and served to speed up implementation throughout the region. The target of 20% renewable energy in the EU by 2020, with the electricity sector taking its lion’s share - 34%. Binding targets at national level provided obligations for nation states to fulfill under threat of EU sanctions. The demand that all 27 Member States should hand in their National Renewable Energy Action Plans by 2010 allowed the EU to monitor progress and hold them to their promises. As a result, green energy has become a pan-European technology field, with the Commission as a major driver.

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 with in mainstream supply, alongside large scale hydro (figure 6).

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6 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.
Hydropower

Although many of the renewable energy technologies are in early end 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 2011). 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.

However, much of the exploitable large scale hydropower has already been utilized, and remaining projects entail conflicts with other use of water, such as irrigation, recreation and fishery; and environmental and social problems, mainly due to inundation of areas by large water 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.

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7 Installed hydropower in Europe totals approximately 179,000 MW. European countries with the largest amounts of hydro include France, Italy, Norway, and Spain (Renewable Energy World 2011). Estimated exploitable hydropower potential in Europe is 1670 TWh/a, but a only 745 TWh/a were actually supplied by hydropower in 1990, and some 1080 TWh/a are expected to be available in 2020 (Lehner et al., 2001; Eurelectric, 1997 (ref by Lehner)).

Although there is a debate around methane emissions from hydropower dams, 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.

8 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 TWh (European Renewable Energy Council). For small hydropower (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 4,000-MW increase over current levels (Hydroworld.com March 2011).
where projects are designed to blend in with nature and the landscape (Hydroworld.com, March 2011)\textsuperscript{9}.

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.

**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 (figure 7)\textsuperscript{10}. 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 of 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 (EWEA 2012). However, China is rapidly outpacing Europe in new capacity.

\textsuperscript{9} The emphasis in Western Europe is retrofitting hydro plants with modern equipment, usually upgrading the capacity of the plant. In Eastern Europe, the focus is rehabilitating aging plants that often were allowed to deteriorate during the era of the Soviet Union.

\textsuperscript{10} A total of 93,957 MW is now installed in the European Union, a growth of 11% on the previous year.
Following saturation of acceptable land sites and conflicts over land use in several European countries, wind power has expanded offshore. Once again Europe has been a lead market with a growth of more than 50% during 2010. The U.K. followed by Denmark and the Netherlands are leading this development.

**Solar**

Following ambitious policy initiatives, Europe has also made extensive advances in photovoltaic electricity. 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, however, Europe continues to be a leading market for photovoltaic installation (figure 8).

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11 The growth rate of PV during 2011 reached almost 70%, an outstanding level among all renewable technologies (EPIA 2011b)
This development was mainly driven by 3 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 121TWh 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 (Figure 9) (Bloem et al/ EC 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 %) (Bloem et al/ EC 2011).
The composition of bio-electricity, however varies from country to country. While Germany has developed a balanced bio-electricity 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 on biogas.

**Technology**

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 has brought industrial prototypes into dynamic learning processes where costs have been driven down several multiples over only a few years. This has resulted in rapid expansion and industrial learning. Competitive expansion in quota markets have driven costs down further. Both wind, solar and several biomass electricity technologies are approaching competitive parity.

The sum of the European technology deployment policies has been central to dramatic technological performance improvement in renewables. The cost evolution of wind and photovoltaics illustrates this progress (figure 10a). For both technologies support policies and niche markets have successfully driven costs down towards competitiveness with incumbent technologies. Similar learning has also taken place in bio-energy (figure 10b).
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).

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 coastal states, ocean energy has a vast potential. The worldwide wave energy contribution to the electricity market is estimated to be of the order of 1-10 TW, which is 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. The world’s first commercial-scale tidal turbine passed the milestone of providing 2 GWh of electricity to the U.K. electricity grid from the waters off Northern Ireland. Ocean energy advances in 2010 included the launch of wave demonstration projects in Sweden. In Norway, the Morild II
floating tidal plant opened in November. Elsewhere, a Pelamis wave device began tests with the German utility company E.ON.

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 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 self-contained 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 centralised generation through efficiency improvement and self-generation. This creates a new dynamic interplay between demand and supply, where the grid increasingly takes on a buffer function between largely self-supplied consumers and downscaled central generation in a multilevel co-ordinated system.

It remains a paradox that while demand side eco-modernity is widely considered to contain some of the lowest hanging fruits in CO2 mitigation (Figure 11), it has been trailing behind supply side approaches both at the policy and industrial levels. This reflects the 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 energy supply, and to reduce emissions of greenhouse gases and other pollutants. It has therefore set itself a target for 2020 of saving 20% of its primary energy consumption compared to projections (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. Over all 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 by 8 % or 0.8% per year in the same period (Bosseboeuf 2012).

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. High initial investment costs may represent a significant financial barrier to the use of energy efficient technologies, especially for private home owners.
Figure 11: 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: EU 2011a

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 decentralised 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 a sub-optimal support for energy efficiency in buildings (DG Energy 2012).

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, cross-cutting demand side eco-modernity is difficult to institutionalize.

Nevertheless, the European Commission is now moving ahead with an energy efficiency directive (EC 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 self-generation 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. Most industries may, for instance, have their energy costs reduced sustainably by automatic control of lighting, sun protection and room climate (EU 2011a).
Demand side eco-modernity does not only involve de-centralised demand-side management, but also 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. 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.

Figure 12 Smart Grid illustration

One decade into the 21st century the 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 but 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 the remote management infrastructure12. 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 member states, such as France, the U.K., and Spain (Greentechmedia, 2012).

12 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) http://www.enel.it/it-IT/ Accessed 2 January 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 energy-saving modernisation of buildings, ranging from refurbishing of windows, increased insulation and other energy efficiency measures. However, it also includes onsite 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& steel, cement, pulp and paper would imply energy savings of more than 30% (IEA 2007). More radical examples can be found in Swedish paper and pulp industry: Södra Cell has, for instance, turned from a conventional large-scale consumer of electricity and fuel to an efficient producer of environmentally friendly fossil-free energy based on waste bark, branches and wood chips that cannot be sold as sawn timber or used in the pulp-making process (ABB 2011).

Besides obvious gains for end users of electricity, de-central producers of renewable energy and smart grid owners, demand side eco-modernity also provides business opportunities for a whole host of industrial actors in construction industry, electronics and information industries, systemic integrators etc.

Discussion

**Who Will Win the Battle?**

After more than a quarter of a century of climate challenge, can we name the winners?

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 development 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 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 coal and gas based technology can only add marginally to this.

The engagement in CCS to deliver a more fundamental transition to close to zero emission has come late and has not yet made 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/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.

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. As opposed to gas, wind and solar are capable of taking European electricity a more fundamental step towards its long term climate goals. However, wind in particular struggles with an intermittency problem that entails a need for complementary stabilizing technology. Furthermore, competing land use and aesthetic consideration pushes wind to more costly offshore sites. Similarly, solar power is challenged by land use issues for centralized applications while its decentralised applications are challenged on aesthetic grounds. Despite obvious successes, eco-modernity still has serious hurdles to overcome.

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 de-regulation, where the commercial efficiency of de-regulated 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 offgrid- 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: (figure 13) Carbon modernity has come up with a viable mid-term solution - 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.
Mainstreaming Eco-Modernity

With the limitation inherent in the gas strategy, as outlined in the gas section, a credible response to the climate challenge - moving forward towards EU’s ambitious 2050 visions - must include mainstreaming of renewables. In other words, merging carbon modernity and eco-modernity under a common regime. This is, however, not a trivial matter.

On the one hand, leading European nations have staged a forceful promotion of new renewables by nationally restricted and technology specific feed in tariffs, based on calculated costs made by public agencies. On the other hand, the mainstream carbon- and nuclear based electricity markets have been gradually deregulated towards a competitive pan-European market with prices set by market rivalry. In the endeavour to mainstream renewables, this dichotomy is no longer sustainable.

One possible approach would be to gradually expand a pan-European green certificate market, and thereby provide a bridge across the niche-market/mainstream market divide. Under an increasing obligatory target for renewables, this scheme introduces a competitive market across renewable...
technologies and providers. By increasing the obligatory renewables target towards 100% and by expanding the arrangement to a broader regional or even European arena the certificate market could become a bridge to full mainstreaming of supply side eco-modernity.

Another, more drastic approach to merging eco-modernity with the established industrial setup, would be to include it into broad pan-European competition under regular el-market directives. On the one hand this would entail exposing wind and solar energy to tough competition from present incumbents. On the other hand, with reductions of implicit and explicit pro-carbon and pro-nuclear subsidies along with a move towards more transparent balancing markets, mature renewables might very soon be competitive.

Intermittency, which has been the Achilles heel of many renewables may be less problematic than imagined. While intermittent wind power causes strain on the North European electricity market, solar power in Germany has been observed to have strong beneficial effects on peak load pricing, especially in the summer season (see figure 14). In this way the solar contribution may lead to extensive reduction of the high peak load costs from thermal power.

_Figure 14 Average Power Prices in Germany 2006 - 2011_  

Source: Rec and Bolkesjø 2012

In addition, full de-regulation should also include realistic pricing of CO2 and other externalities, which would support mature renewables. This would entail a revision of national allocation plans under the European emission trading scheme. These are currently undermining the scheme’s effects, giving large bonuses to carbon incumbents.

Mainstreaming of mature renewable energy would, however, not diminish the need to continue pushing for new technological solutions. Ocean power, new generations of biofuels as well as continued push for CCS, would need continued feed-in support. Furthermore, to reap the full potential of demand side eco-modernity there is a need for a much wider regulatory reform, which would align policy, regulation, and public awareness in a broad range of fields, such as housing, transport, services and industry. Since policies are typically sector-focused, cross-cutting demand
side eco-modernity is difficult to institutionalize. In other words, there is a need to re-regulate beyond sectoral de-regulation.

Will Europe Make It?

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 “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.

The European success in moving partly out of carbon- and over to eco-modernity has been achieved by a strong policy engagement beyond technology policy. It has included a wide variety of policy-instruments, including feed in rights and calibrated feed in tariffs designed to cover investment costs supplemented by quota markets. This has allowed for a broad spectrum of technologies to develop, and has driven learning curves and brought technology development and cost reduction on an unprecedented scale.

A pre-condition for sustained successful climate leadership is for Europe to continue to move on several modernity-frontiers: Having put disproportionate resources into nuclear modernity for half a century after WW II, Europe has currently come around to a more successful pluralist strategy. Building on European diversity in resources, competencies and political preferences, the Continent has produced an interesting variety of climate- approaches. A strength of the European construction, however, is the ability to combine this national pluralism with overarching coordination. Under the coaching of the EU Commission, nation states are held responsible for following up on their green commitments. With a strong influence of the East-European ascension countries with an ambitious catch-up agenda, it remains, however, a challenge to continue to forge ambitious EU positions.

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

In the context of current financial and economics 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 long time. The expanding US and Asiatic markets are providing major roles for non-European players.

While the Danish pioneer, Holding 14.8% of the global market for wind turbines Vestas retained a leading position in 2010, a Chinese company has advanced to the second position, followed by US and other 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 market-share range (table xa).

In photovoltaics Chinese and Taiwanese firms have held six of the ten slots including the top two (Photovoltaic Barometer 2011) (table x1). This development has unfolded rapidly and Chinese firms, in 2010, had more than 50% of the global PV module production, against less than 15% in 2006.

Table 1
Top Wind and Solar Cell Producers Globally

<table>
<thead>
<tr>
<th>WIND</th>
<th></th>
<th>Solar Cells</th>
</tr>
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<tbody>
<tr>
<td>Company</td>
<td>Country</td>
<td>Market share</td>
</tr>
<tr>
<td>Vestas</td>
<td>Denmark</td>
<td>14.3</td>
</tr>
<tr>
<td>Sinovel</td>
<td>China</td>
<td>10.7</td>
</tr>
<tr>
<td>GE Wind</td>
<td>USA</td>
<td>9.3</td>
</tr>
<tr>
<td>Goldwind</td>
<td>China</td>
<td>9.2</td>
</tr>
<tr>
<td>Enercon</td>
<td>Germany</td>
<td>7.0</td>
</tr>
<tr>
<td>Suzlon Group</td>
<td>India</td>
<td>6.7</td>
</tr>
<tr>
<td>Dongfang</td>
<td>China</td>
<td>6.5</td>
</tr>
<tr>
<td>Gamesa</td>
<td>Spain</td>
<td>6.4</td>
</tr>
<tr>
<td>Siemens</td>
<td>Denmark</td>
<td>5.7</td>
</tr>
<tr>
<td>United Power</td>
<td>China</td>
<td>5.7</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>20.2</td>
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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 PV system is created further downstream and closer to the consumers and generates European business and European jobs. Furthermore, while European firms have lost market shares, the relative over-capacity, especially in photovoltaics, following the rapid scale-up of Asiatic 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 figure x, 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 a motivation to stay on the green course.
**Patterns, Dynamics and the Relay Model of Green Transformation**

The European transition out of carbon and nuclear modernity, towards an eco-modern paradigm has involved re-defining political interests, re-orienting civic values, re-shaping business strategies and technological change. However, change has not come without battles. Further, in order to win the battles have to be carefully selected.

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 Commissions 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 besides 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.
While initially legitimated by green anti-nuclear protest movements that spilled over into political power in German politics, the green industrial segment itself built up volume and gradually strengthened its voice alongside incumbents on the European electricity scene. As green technologies matured, following feed-in support, they were also picked up in more mature technology-oriented quota-support systems such as the Swedish green certificate model and are on their way into the regular electricity market.

Our analysis indicates that the European success in pioneering transition towards climate-sustainability lies in an approach that resembles 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 mobilisation. 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 & Koefoed 2003) (figure 15). While strong policies may easily lead to blockage, softer and less confrontational policies with triggering effect 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.

**Figure 15: The Relay Model in Open Game Form**
The lesson from the European experience is that transitions across modernities necessitates 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.

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 Roadmap 2050. Three hurdles need to be overcome, however: 1) accommodation of the new East and Central European “catchup” economies still very much embedded in carbon modernity; 2) tackling of green industrial “leakage” to Asia and 3) institutional inertia in demand side eco-modernisation.
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CERES21 - Creative Responses to Sustainability - is an international research project exploring cultural, political and economic innovation for a sustainable future. The unique features of the CERES21 work include:

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• Exploration of new models of governance for sustainability in a globalizing world;
• Studies of technological innovation and business models for green transition;
• Broad, comparative studies of responses to climate shift and innovation for sustainable future in the poor South (Ghana), the fast expanding East (China), and the rich West (Norway).

The project is financed by The Research Council of Norway.