Mobilizing innovation for the global green shift: The case for demand-oriented innovation policy

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Abstract
This chapter focuses on the role of demand-oriented innovation policies in supporting the global green shift. Three specific cases, all from Europe, in which change has been very quick indeed, are considered: Wind energy in Denmark, the German Energiewende and electrical cars in Norway. The emphasis is particularly on the nature of the policies that were adopted, how they came about, and their impacts on a national as well as global scale. It is shown that demand-oriented innovation policies played a decisive role in all three cases and contributed to encourage (green) innovation, create new jobs and significantly speed up the transition. Moreover, these policies had very important global repercussions.

Keywords
Sustainability; Climate challenge; Green shift; Demand-oriented innovation policy; Renewable energy; Energiewende; Electrical cars;

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1. Introduction

Climate change, mainly caused by emission of climate gases from burning of fossil fuels, is probably the most important challenge facing humankind today (Stern 2015). To avoid the most negative environmental, social and economic consequences that climate change entails, net emission of climate gases has to be reduced to zero by mid-century (IPCC 2018). A vital step would be to phase out fossil fuels and substitute it with renewable energy in energy-production as well as in energy-using sectors (Goodall 2020). This is a very demanding task indeed as 80 % of global energy today is provided by fossil fuels. Extensive change – including a lot of innovation - in the way energy is provided, distributed and used across all parts of society will be required. Moreover, these changes will have to happen much faster than in earlier energy transitions (Wilson 2012, Fouquet 2016, Smil 2016). A crucial question, therefore, is what policy makers can do to mobilize innovation for this purpose (Mowery et al 2010, Fagerberg et al 2016).

Until recently many doubted that renewable energy would ever be sufficient to cater for humanity's needs, mostly because of their (then) high costs. However, continuing innovation in renewable energy technologies, particularly wind and solar, has to a large extent changed these perceptions. In fact, for both wind and solar the costs of producing electricity has diminished year by year (i.e. productivity has increased) as output has expanded. As a result cost-levels for renewables have become substantially lower than those of e.g., nuclear energy plants (Seba 2014), and - in many if not most locations world-wide - on pair with or below plants producing electricity by burning fossil fuels (Goodall 2016). This pattern, i.e., rapidly falling costs, potentially almost unlimited availability and very broad applicability, is as several observers (Mathews 2013, 2014; Stern 2015; Fagerberg 2018) have pointed out, reminiscent of previous technological (industrial) revolutions,[1] and may – if continuing on the same path – have very far-reaching implications(Pearson and Foxon 2012). However, changes in energy production, although very important, will not be enough to reduce emissions to zero, energy-using sectors also have to change their ways.

Moreover, it is important note that the ongoing revolution in renewable energy did not happen all by itself but was decisively influenced by policy-driven change in a few countries, particularly Denmark and Germany. With respect to energy-using sectors, an interesting example of policy-driven change is provided by Norway, with the by far highest penetration of zero-emission vehicles in the world. In all three cases the general thrust of policy was to spur demand for new environmentally friendly technologies, by making these at least as attractive as the more established but less environmentally benign alternatives. These policies led to extensive deployment of the new, environmentally friendly solutions, as well as continuing innovation and cost-reductions, with far-reaching effects both nationally and at a global scale. The nature of these policies, their impacts and how they came about are considered in detail in section 3. As a prelude to that discussion, section 2 makes the case for the role of innovation policy, and particularly demand-oriented innovation policy, in supporting and speeding up transitions, nationally as well as globally. Finally, section 4 comes back what can be learnt from the three cases on policies supporting the global green shift.

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[1] Technological revolutions (or – alternatively – "changes in techno-economic paradigm") are "changes in technology systems (that) are so far reaching in their effects that they have a major influence on the behaviour of the entire economy" (Freeman and Perez 1988, p. 46-7). Such changes are rare; the most recent example is the ICT revolution. See Perez (2002, 2016) for an extended discussion.

2. Mobilizing innovation in large scale transitions: the case for demand-oriented innovation policy

The transition from fossil to renewable energy will, as pointed out above, require extensive technological, economic and social change, that is, a lot of innovation. In this section we are going to discuss, based on the existing literature, how innovation policy may support and speed up such changes.

Some identify innovation policy with support to R&D in firms or public research institutions, i.e., with supporting invention. But this is a much too narrow view. Invention - creation of new ideas for how to do things - and innovation - carrying new ideas out into practice (Fagerberg 2004) - are not the same. As the innovation theorist Joseph Schumpeter[2] pointed out long ago:

"As long as they are not carried out into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring entirely different kinds of aptitudes." (Schumpeter 1934, p. 88).

Moreover, the innovation process extends far beyond the occurrence of the idea itself to include its application/diffusion and subsequent changes based on that, i.e., increased performance and reduced costs through learning (through e.g., interaction with users, von Hippel 2005) and exploitation of economies of scale. As Kline and Rosenberg point out in an influential survey on innovation:

" … most important innovations go through drastic changes in their lifetimes – changes that may, and often do, totally transform their economic significance. The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form" (Kline and Rosenberg 1986, p.283).

Particularly in the case of radical innovation, the first versions are often unpractical, costly devises that have problems in reaching out to customers in large numbers. For example, the first electronic computers, appearing around the second world war, were extremely large, expensive and with little computing power compared to, say, a present-day smart phone, and therefore with very limited market appeal except for the US military and few others. Similarly, when solar cells were invented in the 1950s, they were very costly compared to other ways to generate energy and attracted little commercial interest except – after a while - for use in the US space missions (Jacobsson et al 2004). Thus, as in many other cases market creation by the state, that is demand-oriented innovation policy, turned out to be essential for developing the innovation to the point where it eventually would get broader acceptance and start to make an impact economically (Kemp et al 1998, Mazzucato 2013).

Innovation policy may be defined as public policies that significantly influence innovation (Edquist 2004, Fagerberg 2017).[3] The rationale (legitimation) of such policies is not to promote innovation for its own sake but as a means to support other important goals that policy makers have, from

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[2] For a brief introduction to Schumpeterian theory and its subsequent application by others see Fagerberg (2003).

[3] This chapter focuses on innovation policy developed economies. For a discussion of public policies for industrial upgrading in developing countries, see chapter 10 by Pietrobelli.

economic growth and competitiveness to more specific aims, such as improving health, energy security, or dealing with grand challenges through e.g., carefully crafted “missions” (Mowery 2011, Boon and Edler 2018, Mazzucato 2017). To pursue these goals various “innovation policy instruments” are applied (Edler et al 2016, Edler and Fagerberg 2017), either alone or in combination through so-called policy mixes (Rogge and Reichard 2016), depending on the nature of the challenge at hand (Bergek et al 2012, Borrás and Edquist 2019). It is common to distinguish between system-oriented instruments (for instance supporting interaction through e.g., technology platforms), supply-oriented instruments (R&D support for example), and demand-oriented instruments or policies. Edler and Georghiou (2007, p. 952) define the latter as

“all public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovation, defining new functional requirements for products and services or better articulating demand.”

Many established innovation policy instrument such as R&D support focus mainly on the early phases of the innovation life cycle, e.g., invention (Borras and Edquist 2019). In contrast, demand-oriented innovation policy may be applied in all phases of the cycle including, importantly, diffusion through a range of policy instruments, from using public demand proactively (public procurement for instance) to various measures intended to influence private demand (for example taxes/subsidies, standards, regulations, demonstration programs etc.).

In the early phases of the innovation life cycle, as described by Kline and Rosenberg above, there are usually many competing solutions, volumes tend to be low, and costs and prices high. However, to make a real impact, i.e., attract a sufficiently large number of customers, costs and prices of the new, environmentally friendly technologies need to come down (and quality up) to a level similar (or superior) to the (more polluting) alternatives already in place. This requires further innovation, exploitation of economies of scale, and the development a proper (global) value chain, including a thriving capital goods sector, all of which depend on demand. Hence, during this process demand is to a large extent both cause and effect, so if demand for some reason stalls, the virtuous circle just described may easily abort. That is why demand-oriented innovation policies may be especially relevant to consider when it comes to supporting large scale, transformative change, such as sustainability transitions in energy provision and use (Coenen et al 2015, Boon and Edler 2018).

While innovation policies are mostly national, their impacts may be felt all over the world. For instance, hubs for new, environmentally friendly technologies, supported by innovation policy, may function as global attractors for capital and talent (Marin and Zanfei 2019). However, policy induced demand for new, environmentally benign products in one country may also provide opportunities for entrepreneurs in other countries to enter the market through exports, and, in this way, share in - and benefit from - the rapid learning and innovation activity that characterize such emerging industries. In fact, research from the wind and solar industries indicate that the latter type of policy spillover, i.e., that demand in one country unleashes innovation activity in other countries, may be quite strong (Peters et al 2012, Dechezleprêtre and Glachant 2014). Such global interdependencies may indeed be good news for the global green shift and hence “reinforce the case for stronger environmental policies” (Dechezleprêtre and Glachant 2014, p. 409). Nevertheless, to the extent that policy-makers focus myopically on the domestic economy and disregard beneficial effects elsewhere, such interdependencies may also contribute to make demand-oriented innovation policies more controversial (Peters et al. 2012).

3. Danish wind power

While wind power is an old technology, and was used to produce electricity around already a century ago, the technology did not receive much attention as a source of electricity production before the 1970s. However, the oil-price shocks during that decade made it clear to policy makers and the wider public that relying on imported oil and gas for electricity production may be a risky business, and that it therefore was high time to consider other options. Although in most countries nuclear energy and coal received most attention at the time, wind also attracted some interest (Box 1), particularly by the (increasing) part of the population opposing nuclear. Moreover, while nuclear and coal-fired electricity plants required huge investments, and large organizations to run and distribute the production, wind-power was small scale and hence more attractive for those that wanted, for security or other reasons, to control their own electricity supply, what Morris and Junghohann (2016) call energy democracy.

During the 1970s several initiatives were taken in Denmark, mostly by individuals, to build wind turbines and gradually a social organization of believers with regular "wind meetings", a journal and an association evolved. The 1970s were troubled times economically, and several smaller firms with a background from other sectors of the economy (e.g., suppliers of agricultural machinery, such as Vestas) became interested in exploiting the emerging market for wind-turbines in Denmark as a way to diversify their business. The Danish government was lobbied for support and funding was secured for a small test centre at Risø, which soon became a hub for know-how, support and interaction between users and producers in the field. Moreover, to kick-start the emerging industry the Danish government introduced a 30% subsidy for windmill investments with the purpose of "creating production opportunities for Danish industry in such a way that stable batch-production could be achieved" (van Est 1999, p. 79)[4]. The subsidy was made contingent on approval of the quality of the wind-turbine by the test centre at Risø, further strengthening the role of the centre in the emerging technological innovation system for wind-power in Denmark (Karnøe and Garud 2012). Building on prior experience (see Box 1) the test-centre placed particular emphasis on solid, robust and durable designs suitable for withstanding extreme weather conditions, which became a hallmark of the Danish wind-power industry in the years that followed.

Box 1. Top down or bottom up?

Following the oil-price shock in the early 1970s several countries started to devote more resources to research on other energy sources. Most of this went to nuclear energy but research in wind-energy also received some support. In the case of wind two different R&D strategies were pursued. The dominant approach was what Peter Karnøe characterizes as a top down model. This approach, adopted by for example the governments in the USA, Germany (BRD) and Denmark at the time, was a classic example of the mission-oriented innovation policies pioneered in the USA after the second world war, involving top scientists and engineers and ambitious goals for the technology's

[4] Cited after Karnøe and Garud (2012), p. 742

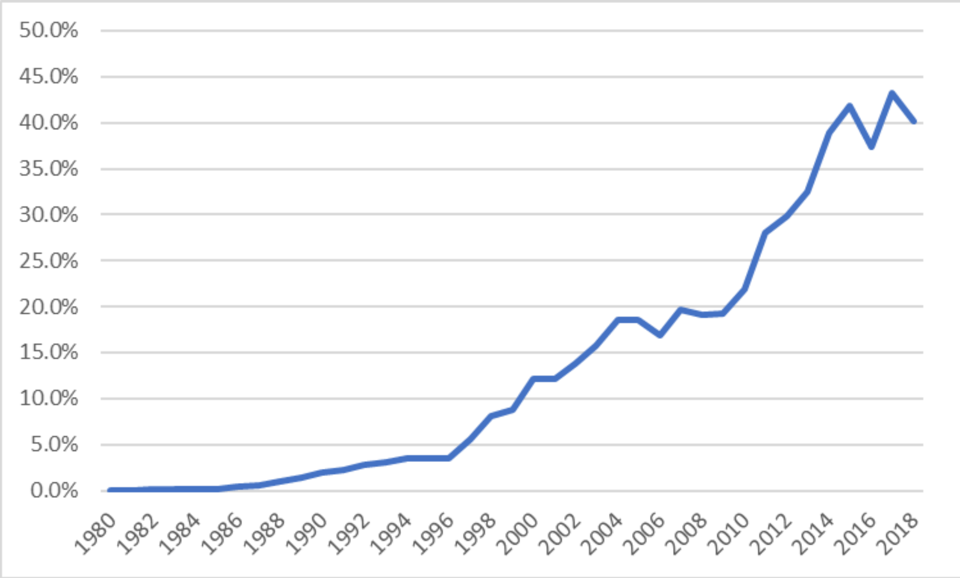
development. The research aimed for a radical scaling up of the technology (i.e. the capacity of the wind turbines) with the expectation that this would reduce costs and make wind energy more competitive. However, after numerous trials none of these high-tech projects succeeded. The large, sophisticated turbines that this research led to, such as Germany's Growian or the MOD-turbines in the USA, were all literally blown apart.

The alternative, bottom-up approach was particularly strong in Denmark but there too it received far less resources than the more fashionable, high-tech alternatives. However, Danish entrepreneurs in this area did not start entirely from scratch, because the Danish engineer J. Juul had already in the 1950s constructed a small-scale wind turbine, which worked flawlessly for at least a decade. The small, Danish firms that entered the then emerging industry were able to build on this design to produce small but robust wind-turbines, which in the years that followed were gradually improved and scaled up through learning (by doing, using etc.). Eventually, it was this bottom-up approach that led to Danish firms becoming global leaders in wind technology at an early stage.

Source: Karnøe 1991.

Despite the subsidy, demand in Denmark was sluggish during the early years (Figure 1). However, for reasons similar to those experienced in Europe at the time, favourable policies in the USA (and in California in particular) opened up a large market for wind-turbines there during the first half of the 1980s, which Danish entrepreneurs were eager to exploit. In fact, according to one source (Karnøe and Garud 2012, p. 744), Danish firms had a market share of 65 % in the Californian market at the peak of the boom in 1986. This contributed to scale up production in Denmark, attract talent and resources (new suppliers of specialized components for instance) and increase public support for the emerging industry. Changes in US policy led in the second half of the decade to a collapse in the Californian market for wind turbines and financial problems for several Danish wind firms. However, at that point Danish firms were about to become global leaders in the emerging industry, and hence in a strong position to compete for contracts both domestically (where demand, partly as the result of policy interventions, picked up in the years that followed) and, not the least, abroad. In many ways Denmark, due to its first-mover advantage, evolved into a global hub for wind-power technology. In the decades that followed the strength of the Danish innovation system for wind-power attracted several foreign firms to locate R&D activities in Denmark, employ Danish skilled personnel or buy Danish wind-power firms (e.g., German Siemens' take-over of Danish Bonus in 2005).

Figure 1. Wind power's share of domestic electricity supply, %



Source: Own calculations based on data from Energistyrelsen, https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik, accessed on 07/08/2020

Danish wind-power policy in the early years was mainly motivated by industrial and environmental policy concerns, issues particularly highlighted by parties to left of the political centre. Policy makers' attention to wind-power got a boost in the mid-1980s from the decision by the Danish parliament to refrain from developing nuclear energy. The (increasing) part of the population taking part in wind power cooperatives, particularly in the countryside, of which there were several thousand, combined with the activities of various environmental organizations (e.g., the strong anti-nuclear movement) , also contributed to keeping wind power on the political agenda. After the phasing out of the initial investment subsidy towards the end of the 1980s, the central policy instrument for supporting wind-power deployment became guaranteed access to the grid combined with a fixed price for the power supplied, i.e., a "feed-in-tariff", designed as to provide a fair (albeit not excessive) return on the investment. The first such scheme – in the form of an agreement between the government and the utilities - was introduced in 1984. However, despite the quite broad popular support for wind-power, politicians on the right were for a long time lukewarm to the idea of the state subsidizing its deployment, and this led to some volatility in policy. In fact, following a deregulation of the energy sector, economic support to wind-power deployment ceased altogether, leading to a full stop in new installations between 2004 and 2008. Nevertheless, the increasing political attention to climate change in Europe and elsewhere, particularly from around the COP 2009 onwards, eventually led to more broad-based political backing in the country for continuing ambitious policies in this area, after which the growth of renewables resumed (Figure 1).[5]

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[5] Since 2009 the support for onshore wind is based on the market price for electricity with a "premium" added to it, financed by consumers through the price paid for electricity. For offshore wind the level of support is decided through auctions. See Irena (2013) for further details.

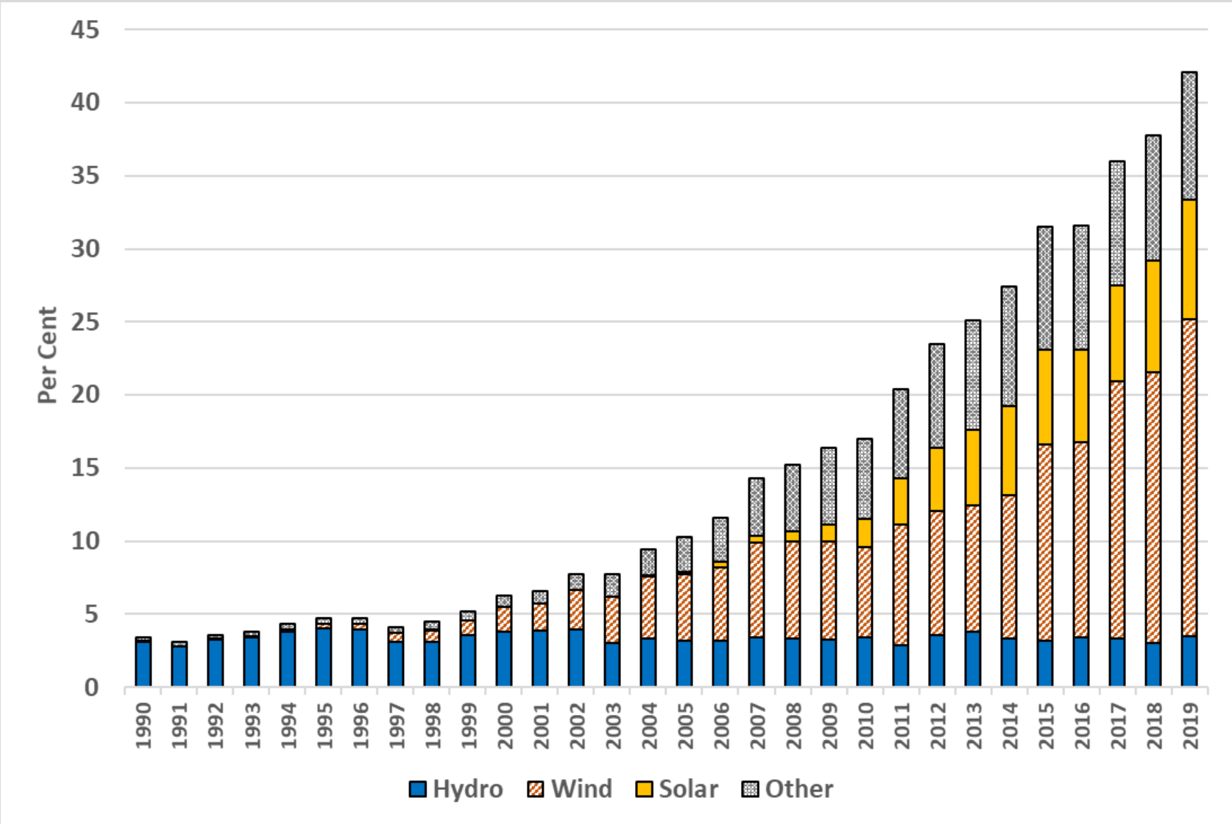
4. The German "Energiewende"

As in Denmark the interest in wind energy started with a small number of enthusiasts, mostly in the country-side, many of which had a background from the anti-nuclear movement. Eventually a social organization of adherents of the technology emerged. Although in the beginning most installations were for local (off-grid) purposes, e.g., heating, gradually the interest in connecting to the grid (and getting a "fair" compensation for it) became stronger. This interest was shared by other producers of renewable energy, e.g., small, independent producers of hydro-electric power. However, grid-connection on what these local producers considered as reasonable terms was difficult to achieve at the time, as the German electricity sector was dominated a small number of large companies, with large investments in nuclear- and coal-based production and distribution of electricity, and with no interest what-so-ever in supporting the development of alternatives to their own business model. In fact, in the years that followed the large incumbents in the energy sector and their allies (such as politicians in coal producing regions) consistently opposed the development of renewable energy in Germany through media interventions, lobbying and lawsuits. This contributed to making the issue of supporting renewables very contentious politically, perhaps more so than in Denmark, which did not possess coal and where the option of developing nuclear energy was laid to rest as early as 1985. In contrast, in Germany the controversy about nuclear energy continued to linger on until the Fukushima-disaster in 2011 eventually led Angela Merkel to replace her support for nuclear with an increased emphasis on renewables.

The controversy about nuclear energy was not only (or mainly) a traditional left-right issue. Many conservative voters (and politicians) in rural communities opposed both nuclear energy and the centralized model of economic development (and distribution of power) that it represented. A law requiring grid-access on fair terms for independent producers of renewable energy, proposed by a conservative parliamentarian, passed parliament in 1990 and came into effect the year after. The law, patterned on the Danish experience, set the feed-in tariff for new renewables to 90% of the retail price of electricity. According to Morris and Jungjohann (2016), the unanimous passing of the law came as a big surprise to the incumbents in the electricity industry, which at the time were preoccupied with taking over the East-German electricity sector.

However, while giving a boost to on-shore wind-energy, the incentives entailed by this arrangement were hardly sufficient for more immature renewable technologies, such as solar energy. As in the case of wind, there had from the late 1970s onwards been some public R&D funding for solar, followed by some demonstration programs in the decades that followed (Jacobsson and Lauber 2006). Still, by the turn of the century, solar energy accounted for only 0,01 % of Germany's electricity production, an almost negligible amount. The new "red-green" government that came to power in 1998 proposed a radical overhaul of the scheme with a technology-specific fixed feed-in tariff (independent on the electricity price) for twenty years. The extra cost of doing so was baked into the electricity price through a surcharge. While fixed for a specific installation (at a certain point in time) future installations of the same type would receive a lower support due to anticipated future technological progress/cost-reductions (automatically declining tariffs). The new scheme, introduced in 2000, led in the years that followed to a surge in investment in renewable energy, much more than foreseen by most experts. This held not only for wind-power but also (and even more so) for solar, for which the level of support through several rounds of adjustment was raised to a much higher level than in the previous decade. Accompanying this rapid increase in deployment (Figure 2), and in the derived demand for capital goods that it led to, a large German industry catering for these needs emerged (Lauber and Jacobsson 2015). Most of these firms, such as the successful wind-turbin supplier Enercon, were new entrepreneurial ventures as the large, established German electrical machinery firms were reluctant to engage in the new industries (or entered at a rather late stage through acquisitions).[6]

Figure 2. Renewables as a share of total German electricity consumption, 1990-2017



Note: Own calculations based on data from Bundesminister für Wirtschaft und Energie, https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html, accessed on 07/08/2020

Viewed as a means to support the transition to environmental sustainability, not only in Germany but worldwide, these policies must be regarded as being very successful. They certainly accomplished much more than anyone would have anticipated beforehand. For example, as late as 1994, the then Minister for the Environment, Angela Merkel, said that “solar, hydro-power and wind-power will not be able to make up more than four percent of power supply even in the long term” (Morris and Jungjohann 2016, p.127). At the time of writing it is above thirty per cent and increasing. German policies in this area can also be credited with creating a global mass-market for solar panels and

[6] See Morris and Jungjohann 2016, p. 50.

related equipment, leading to rapid learning, innovation and reduced costs, helping to spread the technology across the globe and contributing to less green-house gas emissions worldwide. Moreover, the rapidly expanding German market for photovoltaics attracted the interest of Chinese firms, initially mainly for exports but increasingly also for domestic use, helping the much needed transition to sustainability in China itself and in other parts of the developing world (Mathews 2014, Schmitz and Lema 2015). German policy in this area thus has had very encouraging global repercussions.

Nevertheless, in Germany the Energiewende, despite continuing popular support, became quite controversial.[7] First, parts of the political establishment, particularly the FDP (the liberal party), have been against the policy because they see it as excessive interventionism in the working of markets. Similar views have been expressed by many economists in Germany and in the European Commission. The alternative favoured by these critics has often been more indirect measures, particularly the European Union's ETS-mechanism, which however hitherto has proven to be rather ineffective.[8] Second, another faction opposing the policy consists of the large incumbents in the electricity sector and their allies in the coal industry (and affected regions) who saw their economic interests threatened by the growth of renewables.[9] Third, the scheme has been criticized for being too expensive, leading to excessively high costs for consumers and undermining the cost-competitiveness of German businesses. Responding to the concern for competitiveness German governments have in successive rounds exempted a large part of the country's industrial sector from having to pay most of the surcharge financing the scheme (on the basis of their energy intensity). This further added to the costs for ordinary consumers and the remaining part of the private business sector. Fourth, the rapid growth until recently in installed solar power added to these concerns, as more solar due its then very high cost implied a higher surcharge. Finally, a fifth factor weakening the political support in Germany for the policy was that German firms producing solar power equipment faced increasing price-competition from Chinese producers, leading to bankruptcies and a drastic reduction in employment in the part of German industry supplying such goods.

Recently, a controversy arose between the German government and the European commission about the legality of the Energiewende. After a lengthy procedure the European General Court decided in 2016 that the support under the scheme was to be considered as state aid and therefore subject to EU jurisdiction[10]. While the court found the support to renewables to be justified by the purpose of the scheme, it objected to some of the wide-ranging exemptions to (energy-intensive) industry. However, rather than having to revoke (or reduce) the exemptions, the German

[7] See Morris and Jungjohann (2016) for an in-depth discussion.

[8] Between 2011 and 2017 the price in the European Trading System (ETS) for emitting a ton of CO_2 fluctuated around 6 Euro, only a small fraction of what would be necessary for having the desired impact on emissions. More recently the quota price has increased significantly, but it continues to be well below what would be required for being compliant with the goals of the Paris treaty (see e.g., Lewis 2018).

[9] The negative economic impact for the incumbents has to do with the so-called "merit order" in the German electricity grid, which stipulates that the cheapest sources of electricity when measured by marginal costs will be dispatched first. Since renewable power from wind and photovoltaics has close to zero marginal costs, this means that electricity plants driven by fossil fuels risk to be cut out repeatedly, i.e., only run for short periods or not at all, with predictable negative economic consequences for their owners. As the role of renewables grows, nuclear plants also risk being affected, which is a problem for their operators as production at these plants are difficult to scale up or down at short notice.

[10] See, e.g., http://www.europeanpapers.eu/en/europeanforum/surcharges-and-supervision-german-renewable-energy-act-is-state-aid, accessed on 5.12.2018.

government had already decided to undertake a more radical change of policy, the main aim of which seems to be to reduce costs by (1) curbing future growth in renewables, particularly photovoltaics, to a level well below that of preceding years and (2) substitute politically decided feed-in tariffs with remunerations set by auctions. As a result of this policy shift investments in renewables have declined significantly, and were in 2019 less than one half of what they were in the beginning of the decade.[11] Whether the reduced ambitions that this policy shift entails are consistent with the long run objectives for the transition (that German politicians have agreed to) seem questionable, given that in 2019 - despite an impressive increase (especially in the electricity sector) – less than one fifth of German energy comes from renewable sources. The policy change also implies that it has become more demanding for smaller actors, such as individuals or community-based groups, to take active part in the transition. This may be matter of concern, since much of the success of German policy in this area hitherto rests on the ability to mobilize large parts of the population for this purpose.

5. Electromobility in Norway

Electromobility is not a new idea. In fact, in the early years of the automobile industry electric cars were more common than petrol-driven cars but eventually the latter technology prevailed. The oil-crises of the 1970s led to a renewed interest in electric cars in several countries, and in the years that followed both new entrepreneurial firms and established incumbents started to engage with the technology on an experimental basis, leading to a small number of battery-driven electric cars being produced in a number of countries. Most of these were small city-cars, with a quite limited range but a high price-tag, thus not very attractive beyond the technology's most ardent supporters. Nevertheless, in 1990 a newly founded Norwegian environmental NGO decided to import one such car and applied successfully to the government for exemption of the (very high) Norwegian registration tax, which - based as it was on the value of the car - would have made electric cars prohibitively expensive in the Norwegian market.

However, the precedent thus set was of interest to local entrepreneurs considering joining the emerging electric car industry, and during the years that followed several such attempts were made, the most well known being the Pivco - later Think – company, which during its life time produced a few thousand electric cars (Asphjell 2013). During the early phase the company received some economic support to developing its product from various parts of government. The city of Oslo, which suffered from local air pollution, was very supportive to the spread of electric cars, and introduced several advantages for such cars early on, as free parking and charging. Over the years national policy-makers, often following up on local initiatives from Oslo, agreed to a number of additional advantages for owners of electric cars, i.e., exemptions from fees on toll roads (1997), zero value added tax (2001) and the right to use bus lanes (2003). The municipality of Oslo was also instrumental in starting up an association promoting electric cars (1995), which still exists, and currently has over 75 000 members[12] (Figenbaum 2016). While reduction of local air pollution was often mentioned as a legitimation for these schemes, industrial policy concerns – i.e. the possibility

[11] For sources to numbers mentioned in this paragraph see https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html, accessed on 07/08/2020

[12] See https://elbil.no/om-norsk-elbilforening/ , accessed on 25/08/2020

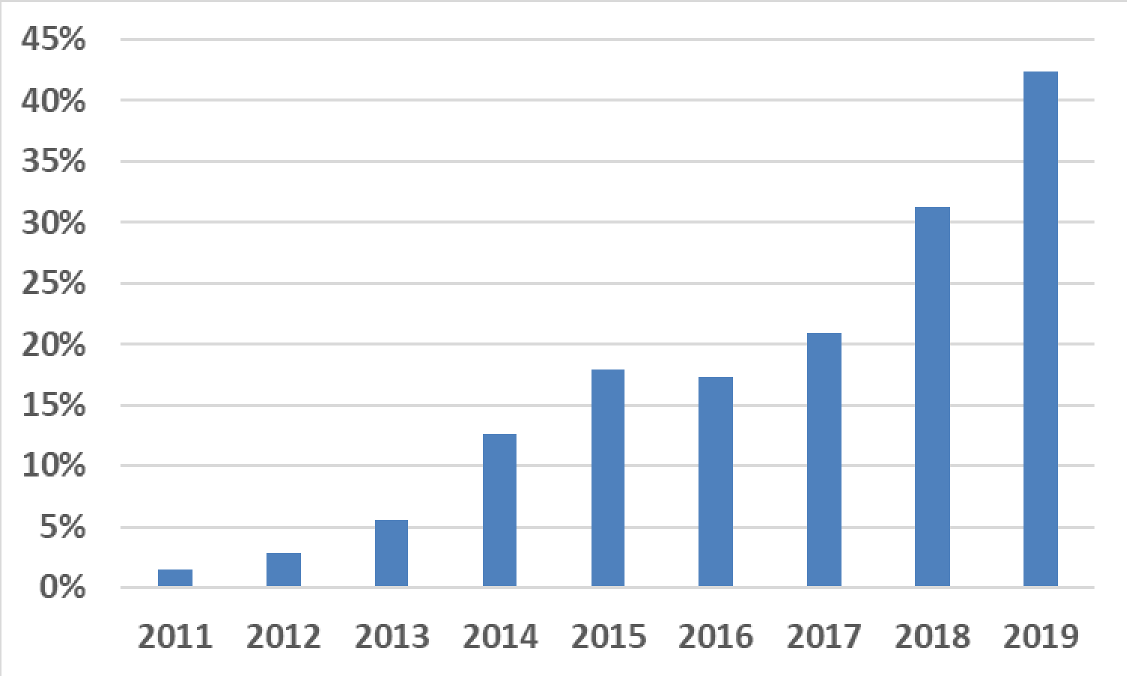
of supporting the growth of a new industry in Norway - probably also played a role at an early stage (Røste 2001).

Despite relatively favourable public policies for buyers, sales of electric cars in Norway were sluggish during the early years and it proved difficult for Think to attract investors willing to finance the step from prototypes to regular production/marketing. Nevertheless, a new market opportunity for electric cars emerged around the turn of the century due to the need for the car industry to develop "Zero Emission Vehicles" (ZEV) if they wanted to retain their presence in the lucrative Californian market. Ford acquired Think for this purpose, and for a few years the prospects looked quite rosy, but after the ZEV program was abandoned Ford rapidly lost interest and sold Think to a foreign investor who failed to save the firm. A final attempt to revive the company was made in the second half of the decade, just to fail once more with the emergence of the financial crisis. Arguably, lacking knowledge about car production, a solid financial backing and a sufficiently large (and growing) domestic market, the emerging industry faced an uphill struggle from day one. However, is difficult to avoid the conclusion that policy makers did little to support the emerging industry when it ran into trouble.

However, the many incentives offered to potential users of electric cars finally resulted in increased domestic demand during the early/mid 2000s, particularly in the Oslo region. At the time, the Think company was because of its financial problems not able to deliver cars. To meet the demand some imports of used electric cars (some of which were originally produced in Norway!) from other countries took place (Figenbaum and Kolbentvedt 2013). But from the end of the decade onwards first Mitsubishi (with its I-MiEV model) and then other incumbents in the industry, such as Nissan and Volkswagen, entered the growing Norwegian market with new models, which were both more comfortable and had a longer range than what had been available hitherto, and hence had a broader appeal to consumers. As a result, sales of battery-driven electrical vehicles soared, from 1 % of all new cars in 2011 to 42% in 2019 (Figure 3), far higher than in other European countries.[13]

[13] The slight dip in the share from 2015 to 2016 was caused by a tax change that made hybrid cars (cars with two engines, one of which electric) much cheaper than before. This led to a sharp increase in sales for hybrid cars in 2016, from 12.4 per cent of total sales in 2015 to 24.5 per cent, at the expense of both fossil and zero-emission vehicles (Source: http://www.ofvas.no/).

Figure 3. Norway: Electric cars (no emissions) as a share of all new private cars



Source: Own calculations based on data from http://www.ofvas.no/, accessed on 07/08/2020

As the numbers of electric cars increased, and especially with the arrival of electric luxury cars (e.g., TESLA), critics started to question the relevance of the advantages offered to the owners of such cars and instead emphasize the costs (loss of income for the state for example) and the various problems that the increasing number of such cars might lead to (such as congestion in bus lanes or increased use of cars at the expense of walking or using public transport). However, gradually climate policy goals had become more central to policy discussions in Norway, and this led to increased political support for continuing diffusion of electric cars. In fact, it had become clear to Norwegian policymakers that electrification of the transport sector was perhaps the easiest way for Norway to reduce its emissions in line with the goals European politicians and the world at large had agreed to. A broad "climate agreement" in parliament in 2012 concluded that "electrical vehicles and hydrogen incentives will be frozen until the next parliamentary term (i.e. at the end of 2017), if the number of electrical vehicles does not exceed 50 000 before that time".[14] However, although in 2012 50 000 electrical cars in Norway may have looked as a distant goal, it was attained already in April 2015. Nevertheless, at the time of writing it appears that the continuing electrification of transport has been accepted by all political parties and other relevant actors such as NGOs, major businesses etc. In fact, in 2017 the responsible minister in the present (right of centre) government announced that policy will make sure that only ZEVs are sold in Norway in 2025.[15]

[14] Cited after Figenbaum and Kolbentvedt (2013), p. 24.

[15] Vidar Helgesen in interview with E24, 16.06.2017, http://e24.no/energi/bil/klimaministeren-skal-gjoere-bensinbiler-helt-uinteressant-aa-kjoepe/24074852, accessed on 5.12.2018

Conclusions

What are the main takeaways from the discussion in this chapter?

A key lesson is that demand-oriented innovation policies, the main policy approach adopted in all three cases, had powerful effects on the spread of the three environmentally friendly technologies under study here. In fact, these effects were much larger – and quicker - than foreseen by policy-makers or experts. This indicates that the potential users, e.g., the common public, were happy to change to more environmentally benign solutions, especially when they were compensated for some of the extra costs of doing so. Their motivations were not necessarily purely economic, however. Many simply wanted to do something they regarded as socially beneficial (Ostrom 2010),that is, supporting safe, clean technologies for production and use of energy at the expense of the more dangerous, polluting alternatives already in place. Particularly for renewable energy these sentiments became much strengthened by the increasing popular resistance towards nuclear, fueled by events such as the Three Mile Island nuclear accident in 1979, the Chernobyl disaster in 1986, and the Fukushima-catastrophe in 2011. The small scale of wind and solar plants, and the possibility for local, decentralized control that this allowed for (so-called "energy democracy", Morris and Jungjohann 2016), was another feature that users found attractive.

In fact, in all three countries, the (initial) driving force of these policies was not policy makers at the national level, but popular movements (or networks) composed of concerned citizens, environmental lobbies, technology enthusiasts and small entrepreneurs, united by a common interest for improving the conditions for developing and spreading the new, environmentally friendly technologies. The general thrust of their demands was to support deployment, by making the technology at least as attractive as the more established, less environmentally friendly, alternatives. The resistance to the suggested policy changes came from two sources in particular. One was fueled by established economic interests that, perhaps rightly, considered the new policy as threatening to them; this was especially the case in Germany. Another source of resistance, more ideological in nature, came from economists and parts of the political establishment, who looked upon such deployment friendly schemes as excessive intervention in the working of markets, the German FDP party's criticism of Energiewende is illustrative in this regard. However, during the first decades of the new millennium it became increasingly evident that to avoid the most negative consequences of climate change, net emission of climate gases had to be reduced to zero by mid-century (IPCC 2018), and that replacing fossil fuels with clean, renewable energy in energy-production and use would be a necessary step towards this goal. This provided additional legitimacy to the demand-oriented innovation policies discussed in this chapter and contributed to – at least for the time being - laying to rest various attempts to abolish these policies.

Another takeaway is that these demand-oriented policies contributed significantly to stimulate innovation, create new jobs[16] and reduce costs and prices, with the implication that all three technologies have become – or are on the path towards being - competitive with the more traditional, less environmentally benign alternatives. The German policy approach towards innovation in renewables, adopted around the turn of the century, was particularly effective in encouraging innovation, as it focused on not just one but a portfolio of technologies at different

[16] "Project-level data indicates that, on average, renewable energy creates more jobs than fossil-fuel technologies. Solar PV, for instance, creates more than twice the number of jobs per unit of electricity generation compared with coal or natural gas." (Irena 2017, p. 6)

degrees of maturity, thus avoiding the danger of pre-mature “lock-in” to a specific solution. Arguably, without Germany’s policy-induced deployment of (at the time) high cost solar energy, this technology might not have progressed at the pace it did.

Moreover, as illustrated by the three cases considered here, demand-oriented innovation policies may have effects far beyond the country in which they were adopted. For example, US support for deployment of wind energy during the 1980s created opportunities for Danish wind-energy firms. Closer to our own time, Germany’s support for deployment of solar energy created a global market for solar panels and other types of equipment, which Chinese firms were eager to exploit. This led to increased competition, rapid productivity growth, as well as decreasing costs and prices, paving the way for rapid deployment of solar energy world-wide and, hence, contributing to the much-needed global green shift. Nevertheless, German solar energy equipment firms were negatively affected by the increasing competition, leading to a weakening of the legitimacy of continuing support to solar energy in the country. This points to an important challenge for policy-makers. To the extent that the purpose of policy is not only to promote the transition to clean energy, but also to generate income and jobs in a specific country or region, demand-oriented innovation policy instruments, though necessary, may not be sufficient.

One possible answer to this challenge might be to try to internalize such spillovers through increased international cooperation in innovation policy (Smith 2017). The European Union’s “European Green Deal”[17] may be seen as an attempt to do just that. In general, however, more complex goals require broader and more sophisticated policy mixes (Rogge and Reinhard 2016, Reichard and Rogge 2016). After all, demand – although of critical importance – is only one of several factors required for success in innovation, e.g., knowledge, skills and finance are also needed, and failure to provide any those may easily kill any emerging green venture (Fagerberg 2017). For example, the emerging Norwegian electrical car industry struggled with several challenges, but the major obstacle was arguably lack of finance, which policymakers at the time did little to address. Hence, to successfully combine the goal of a green shift with that of growth and jobs, a more holistic approach to innovation policy (Borras and Edquist 2019), in which the various challenges are identified and addressed through appropriate policy instruments (and mixes), might be required. Such holistic policy making is demanding, however, as it would require policymakers in many different settings (as well as stakeholders outside government) to cooperate and align their actions (Fagerberg and Hutschenreiter 2020).

[17] See https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en , accessed on 25.08.2020

References

Asphjell, A., Asphjell, Ø., Kvisle, H.H. (2013). Elbil på norsk 2013, Trondheim, Transnova

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A. (2008) Analyzing the functional dynamics of technological innovation systems: A scheme of analysis, Research Policy, 37 (3), 407–429.

Boon,W. and J Edler (2018) Demand, challenges, and innovation. Making sense of new trends in innovation policy, Science and Public Policy 45 (4), 435-447

Borrás, S. and C Edquist (2019) Holistic Innovation Policy: Theoretical Foundations, Policy Problems, and Instrument Choices, Oxford: Oxford University Press

Coenen,L., T. Hansen and J.V. Rekers (2015) Innovation policy for grand challenges. an economic geography perspective, Geography Compass 9 (9), 483-496

Dechezleprêtre, A. and M. Glachant (2014) Does Foreign Environmental Policy Influence Domestic Innovation? Evidence from the Wind Industry, Environ Resource Econ 58:391–413

Edler, J., P. Cunningham and A. Gök (2016) Handbook of innovation policy impact, Edward Elgar Publishing

Edler, J. and Fagerberg, J. (2017) Innovation policy: what, why, and how, Oxford Review of Economic Policy 33 (1), 2-23.

Edler, J. and Georghiou, L. (2007) Public procurement and innovation – Resurrecting the demand side, Research Policy, 36 (7), 949–963.

Edquist, C. (2004). "Systems of Innovation: Perspectives and Challenges" in Fagerberg, J., Mowery, D., and Nelson, R (eds.) Oxford Handbook of Innovation, Oxford: Oxford University Press, p. 181-208

Fagerberg, J.(2003) Schumpeter and the revival of evolutionary economics: an appraisal of the literature, Journal of Evolutionary Economics 13:125-159

Fagerberg, J.(2004) Innovation: A Guide to the Literature, in Fagerberg, J., Mowery, D., and Nelson, R. eds. (2004) The Oxford Handbook of Innovation, Oxford: Oxford University Press, p. 1-26

Fagerberg, J. (2017) Innovation Policy: Rationales, Lessons and Challenges, Journal of Economic Surveys 31(2), 497–512

Fagerberg, J. (2018) Mobilizing innovation for sustainability transitions: A comment on transformative innovation policy, Research Policy 47 (9), 1568-1576

Fagerberg, J. and G. Hutschenreiter (2020) Coping with societal challenges: Lessons for innovation policy governance, Journal of Industry, Competition and Trade 20 (2), 279–305.

Fagerberg, J., Laestadius, S. and Martin, B.R. (2016) The Triple Challenge for Europe: The Economy, Climate Change, and Governance, Challenge, 59 (3): 178-204

Figenbaum, E. (2016) Perspectives on Norway's supercharged electric vehicle policy, Environmental Innovation and Societal Transitions, https://doi.org/10.1016/j.eist.2016.11.002

Figenbaum, E, and M. Kolbenstvedt (2013). Electromobility in Norway - experiences and opportunities with Electric Vehicles, Report 1281/2013, The Institute of Transport Economics , (https://www.toi.no/publikasjoner/elektromobilitet-i-norge-erfaringer-og-muligheter-med-elkjoretoy-article32103-8.html, downloaded on August 21, 2017).

Fouquet, R. (2016) Lessons from energy history for climate policy: Technological change, demand and economic development, Energy Research and Social Science 22, 79-93

Freeman, C. and Perez, C. (1988) "Structural Crises of Adjustment: Business Cycles and Investment Behaviour", in Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G. and Soete, L. G. (eds.), Technical Change and Economic Theory, London: Pinter, p. 38-66.

Goodall, C. (2016) The Switch: How solar, storage and new tech means cheap power for all, London: Profile Books

Goodall, C. (2019) What we need to do now – for a zero carbon future, London: Profile Books

IPCC (2018) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, https://www.ipcc.ch/sr15/, downloaded on August 5, 2020

Irena (2013) 30 Years of Policies for Wind Energy – Lessons from 12 Wind Energy markets, https://www.irena.org/DocumentDownloads/Publications/IRENA_GWEC_WindReport_Full.pdf, downloaded on August 21, 2017

Irena (2017) Renewable Energy and Jobs, Annual Review 2017, http://www.irena.org/documentdownloads/publications/irena_re_jobs_annual_review_2017.pdf, downloaded on August 21, 2017

Jacobsson, S. and V. Lauber (2006) The politics and policy of energy system transformation—explaining the German diffusion of renewable energy technology, Energy Policy 34 (3), 256-27

Jacobsson, S., Sandén, B. and Bångemns, L. (2004) Transforming the Energy System—the Evolution of the German Technological System for Solar Cells, Technology Analysis & Strategic Management 16:1, 3–30

Karnøe, P. (1991) Dansk Vindmølleindustri - en overraskende international success: Om innovationer, industriudvikling og teknologipolitik, Copenhagen: Samfundslitteratur

Karnøe, P.; Garud, R. (2012) Path Creation : Co-creation of Heterogeneous Resources in the Emergence of the Danish Wind Turbine Cluster, European Planning Studies, Vol. 20, No. 5, p. 733-752.

Kemp, R., Schot, J. and Hoogma, R. (1998) Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. Technology Analysis and Strategic Management 10(2): 175–198.

Kline, S.J. and Rosenberg, N. (1986) "An Overview of Innovation", in Landau, R. and Rosenberg, N. (eds.) The Positive Sum Strategy: Harnessing Technology for Economic Growth, Washington D.C.: National Academy Press, p. 275-304

Lauber, V. and S. Jacobsson (2015). 'Lessons from Germany's Energiewende', in Fagerberg, J., S. Laestadius and B. R. Martin (2015), The Triple Challenge for Europe: Economic Development, Climate Change and Governance, Oxford: Oxford University Press, pp.173-203.

Lewis, Mark (2018) Carbon Clampdown – Closing the Gap to a Paris-compliant EU-ETS, www.carbontracker.org, addressed on December 3, 2018

Marin G., Zanfei A. (2019) Does Host Market Regulation Induce Cross Border Environmental Innovation? The World Economy, 42:2089–2119.

Mazzucato, M. (2013) The entrepreneurial state: debunking private vs. public sector myths. Anthem Press, London, UK.

Mazzucato, M. (2017) Mission-Oriented Innovation Policy: Challenges and Opportunities, London: RSA,https://www.thersa.org/globalassets/pdfs/reports/mission-oriented-policy-innovation-report.pdf, addressed on 30.11.2017

Morris, C., Jungjohann, A. (2016) Energy Democracy - Germany's Energiewende to Renewables, Basingstoke: Palgrave MacMillan

Mathews, J. A. (2013) The renewable energies technology surge: A new techno-economic paradigm in the making? In Futures 46, p. 10-22

Mathews, J. A. (2014). Greening of Capitalism: How Asia Is Driving the Next Great Transformation, Stanford: Stanford University Press.

Mowery, D.C., R.R. Nelson and B.R. Martin (2010). 'Technology Policy and Global Warming: Why New Policy Models are Needed (Or Why Putting New Wine in Old Bottles Won't Work)', Research Policy, 39, pp.1011-1023.

Mowery, D.C. (2011), Federal Policy and the Development of Semiconductors, Computer Hardware and Computer Software: A Policy Model for Climate Change R&D?, in Rebecca M. Henderson and Richard G. Newell (eds), Accelerating Energy Innovation: Insights from Multiple Sectors, Chapter 5, Chicago, IL: University of Chicago Press, 159–88

Ostrom, E. (2010) Polycentric systems for coping with collective action and global environmental change, Global Environmental Change 20 (4), 550–557

Perez, C. (2002) Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages, Cheltenham: Edward Elgar

Perez, C. (2016) Capitalism, Technology and a Green Global Golden Age: The Role of History in Helping to Shape the Future, in Jacobs, M. and Mazzucato. M. (eds.) Rethinking Capitalism: Economics and Policy for Sustainable and Inclusive Growth, The Political Quarterly, Chichester: Wiley-Blackwell, p. 191-207

Pearson, P. J. G. and Foxon, T.J. (2012) A low carbon industrial revolution? Insights and challenges from past technological and economic transformations, Energy Policy 50, 117-127

Peters, M., M. Schneider, T. Griesshaber and V. H. Hoffmann (2012) The impact of technology-push and demand-pull policies on technical change – Does the locus of policies matter? Research Policy 41: 1296– 1308

Reichard, K. and K.S. Rogge (2016) How the policy mix impacts innovation: Findings from company case studies on offshore wind in Germany, Environmental Innovation and Societal Transitions 18 62–81

Rogge, K.S. and K. Reichardt (2016) Policy mixes for sustainability transitions: An extended concept and framework for analysis, Research Policy 45 (8), 1620-1635

Røste, R. (2001) Næringspolitikk for konkurransedyktige nyetableringer - en casestudie av den elektriske bilen Think fra idé til marked, Master-oppgave, Universitetet i Oslo, https://www.duo.uio.no/handle/10852/13555, addressed on 15.08.2017

Schmitz, H. and R. Lema (2015). 'The Global Green Economy: Competition or Cooperation between Europe and China?', in Fagerberg, J., S. Laestadius and B. R. Martin (2015), The Triple Challenge for Europe: Economic Development, Climate Change and Governance, Oxford: Oxford University Press, pp.119-142

Schumpeter, J. A. (1934) The Theory of Economic Development, Cambridge, Mass: Harvard University Press.

Seba, T. (2014) Clean Disruption of Energy and Transportation: How Silicon Valley Will Make Oil, Nuclear, Natural Gas, Coal, Electric Utilities and Conventional Cars Obsolete by 2030, Silicon Valley, California: Clean Planet Ventures

Smil, V. (2016) Examining energy transitions: A dozen insights based on performance. Energy Research & Social Science 22:194-197

Smith, K. (2017) Innovating for the global commons: multilateral collaboration in a polycentric world, Oxford Review of Economic Policy, Volume 33, Issue 1, Pages 49–65

Stern, N. (2015) Why are We Waiting?: The Logic, Urgency, and Promise of Tackling Climate Change, The MIT Press van Est, R.(1999) Winds of change : a comparative study of the politics of wind energy innovation in California and Denmark, Utrecht : International Books

von Hippel, E. (2005) Democratizing Innovation, Cambridge, MA: MIT Press

van Est, R.(1999) Winds of change : a comparative study of the politics of wind energy innovation in California and Denmark, Utrecht : International Books

Wilson, C. (2012) Up-scaling, formative phases, and learning in the historical diffusion of energy technologies, Energy Policy 50: 81-94