List of Abbreviations

ARPA-E	Advanced Research Project Agency-Energy (USA)
ARRA	American Recovery and Reinvestment Act
AWEA	American Wind Energy Association
BDEW	Bundesverband der Energie und Wasserwirtschaft (The Association of Energy and Water Industries [Germany])
BDI	Bundesverband der Deutschen Industrie (Federation of German Industries [Germany])
BEE	Bundesverband Erneuerbare Energie (The German Renewable Energy Federation [Germany])
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Research and Technology [Germany])
BMU	Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (Federal Ministry for the Environment [Germany])
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy [Germany])
BSW-Solar	Bundesverband Solarwirtschaft (German Solar Industry Association)
Btu	British thermal unit
BWE	Bundesverband Windenergie (Federal Wind Energy Association [Germany])
CCS	carbon capture storage
CDU	Christlich Demokratische Union Deutschlands (Christian Democratic Union of Germany)
CMA	China Meteorological Administration
CSU	Christlich-Soziale Union in Bayern (Christian Social Union in Bavaria [Germany])
CTL	coal-to-liquids
DEA	Danish Energy Agency (Energistyrelsen)
DoD	Department of Defense (USA)
DoE	Department of Energy (USA)
DPJ	Democratic Party of Japan
EEG	Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act [Germany])
EIA	U.S. Energy Information Administration

EPA	United States Environmental Protection Agency
EPIA	European Photovoltaic Industry Association
EREF	European Renewable Energies Federation
ETS	European Emissions Trading Scheme
EWEA	European Wind Energy Association
FBR	fast breeder reactor
FDP	Freie Demokratische Partei (Free Democratic Party [Germany])
FIT	feed-in tariff
GE	General Electric
GHGs	greenhouse gases
GW	gigawatt
GWEC	Global Wind Energy Council
IEA	International Energy Agency
JPEA	Japan Photovoltaic Energy Association
JWPA	Japan Wind Power Association
LDP	Liberal Democratic Party (Japan)
LNG	liquid natural gas
mb/d	million barrels per day
MEP	Ministry of Environmental Protection (China)
METI	Ministry of Economy, Trade, and Industry (Japan)
MITI	Ministry of International Trade and Industry (Japan)
MOE	Ministry of the Environment (Japan, Norway)
MOF	Ministry of Finance (China, Japan)
MOFA	Ministry of Foreign Affairs (Japan)
MOPE	Ministry of Petroleum and Energy (Norway)
MOST	Ministry of Science and Technology (China)
MW	megawatt
NCPA	Norwegian Climate and Pollution Agency
NCS	Norwegian Continental Shelf
NDRC	National Development and Reform Commission (China)
NEA	National Energy Administration (China)
NEDO	New Energy and Industrial Technology Development Organization (Japan)
NHO	Næringslivets Hovedorganisasjon (Confederation of Norwegian Enterprise)
NIMBY	not in my backyard
NPD	Norwegian Petroleum Directorate
NRA	Nuclear Regulatory Agency (Japan)
NVE	Norges vassdrags- og energidirektorat (Norwegian Water Resources and Energy Directorate)

OED	Olje- og energidepartmentet (Ministry of Petroleum and Energy [Norway])
OLF	Oljeindustriens Landsforening (Norwegian Oil Industry Association)
PPP	purchasing power parities
PTC	Production Tax Credit (USA)
PV	photovoltaic
REL	Renewable Energy Law (China)
RPS	Renewable Portfolio Standard
SEIA	Solar Energy Industries Association (USA)
SERC	State Electricity Regulatory Commission (China)
SOE	state-owned enterprise
SPD	Sozialdemokratische Partei Deutschlands (Social Democratic Party of Germany)
StrEG	Stromeinspeisungsgesetz (Electricity Feed-in Law [Germany])
TEPCO	Tokyo Electric Power Company, Incorporated (Japan)
TIC	techno-institutional complex
TPES	total primary energy supply
TWh	terawatt hours
VC	venture capital
VDEW	Verband der Elektrizitätswirtschaft (The Association of Electrical Industry [Germany])
WWEA	World Wind Energy Association

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Introduction

In 2013, Chinese President Xi Jinping declared that China will no longer sacrifice the environment for temporary economic growth (*CCICED*, 2013); a year later Premier Li Keqiang followed up by stating that China 'will resolutely declare war against pollution as we declared war against poverty' (*Guardian*, 2014a; GWEC, 2014, p.14). Whether China lives up to its promises obviously remains to be seen, but clearly environmental and energy issues now attract serious attention from very powerful political and industrial actors. In a world where oil prices, despite their recent dramatic fall, had long been stable at more than US$ 100 per barrel, where peak oil (as in the point of maximum oil production (after which it will inevitably decline)) is fast approaching, and where climate change is becoming an evermore concrete and tangible challenge, a fresh look at energy policy, and renewable energy policy in particular, is very much in order.

Chinese authorities are not alone in taking these issues seriously. (Rather, their statements reveal a somewhat belated emphasis of their importance.) Since the 2011 earthquake, tsunami and nuclear meltdown at Fukushima, both Japan and Germany have gone a long way toward ending their dependence on nuclear power. In the US, every president since Richard Nixon has concerned himself with energy security. President George W. Bush in 2006 warned that 'America is addicted to oil.' In 2010 President Barack Obama urged the US to make serious investments in clean energy rather than just surrendering the clean jobs of the future to Germany and China, and in 2014 he used the Environmental Protection Agency (EPA) to bypass a gridlocked Congress and impose stricter regulations on the power sector (in particular, the coal industry) (*EPA*, 2014b; *New York Times*, 2006; *White House*, 2010). In Denmark, the parliament has decided that by 2050 the Danish energy system will be fossil free (Lund et al., 2013). And in Norway, former Prime Minister Jens Stoltenberg in his 2007 New Year's speech somewhat pompously labeled the development of Carbon Capture Storage (CCS) technology as Norway's equivalent of the moon landing, and its contribution to solving the world's energy and climate problems (*VG*, 2007).

Some of these initiatives and utterances may prove to have been little more than rhetoric and lofty plans. After all, worldwide emissions have never been higher than in 2013.[1] But even lofty plans and rhetoric often provides a suggestion as to which way the wind blows, and about what stirs the public imagination. It is certainly clear that energy issues are at the forefront of the political discourse like never before. Energy security no longer just means more oil on bigger oil tankers. It means that we, to an ever greater extent, need to come up with new ways of producing energy (as well as new ways to reduce energy consumption). And preferably, the new energy alternatives need to be far less polluting than the old ones. If not, the Chinese war on pollution would be lost before it had even gotten underway, and the Danish plan to become fossil free would be nothing but fine words on glossy paper. While there is no single solution to these problems, it is very hard not to see renewable energy as one of them.

So, renewable energy must be pretty important, then? The question may seem puzzling. But the first and most obvious answer is that, in and of itself, it really is not. Out of global final energy consumption, renewable energy (not including hydro) accounts for no more than 1.2 percent (2.0 if biofuels are included), and out of all global electricity production, the wind and solar share is 3.6 percent, with 2.9 percent for wind and 0.7 for solar (see Figure 1.1).[2] These numbers increase year by

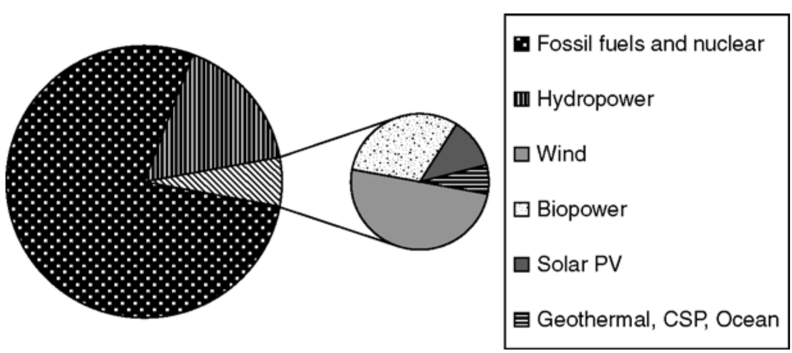

Figure 1.1 Renewable share of electricity production, 2013
Source: REN21 (2014).

year, but they are still very small, and fossil fuels provide a fairly steady 80 percent of our energy (REN21, 2014). So, why spend an entire book on something that accounts for only a little more than 1 percent of global energy consumption?

The more roundabout answer is that the world is currently facing, or in the midst of, a number of different crises. Some are immediate, some are drawn-out, and others are mainly about the future. But since 2008 we are in the midst of a financial crisis. It is the biggest economic crisis the world has faced since 1929, and it has been particularly protracted in Europe. In China, stimulating renewable energy industries – industries perceived as major growth industries of the future – was part of the Chinese government's plan for China to keep growing through the crisis, and notions of renewable industry heading a wave of green economic growth was much heard both in Europe and in the US. Second, we may be looking at an energy crisis. By all means, this is a different kind of crisis than the financial crisis and we are slowly adjusting to a world where oil is far costlier than a mere decade ago, but when the oil price started climbing, the increase was extremely abrupt, from less than $20/barrel in 2002 to $50 in 2007, before peaking at $147/barrel in 2008. It has fluctuated considerably since then, but since 2011 only rarely dipped below $100/barrel. Granted, at the time of writing, and in less than a year, the oil price has more or less halved, currently standing at around $60/barrel, analysts warning that the dip may be more than just temporary. Still, the long-term forecasts are for prices to once again increase. The International Energy Agency (IEA) (2013c) predicts $128/barrel by 2035, and before the oil price started crashing, an IMF working paper suggested as much as $180/barrel already by 2020 (Ayres, 2014). This estimate is now unlikely to be fulfilled, but it does suggest that eventually prices will inexorably start rising again.

The oil price contributes to the financial crisis in the sense that energy prices this high are undoubtedly bad for the overall economy. However, the real energy crisis is more of a drawn-out thing. Peak oil has been a concern for decades, and while it represents no immediate problem (we keep pushing it into the future), it is quite obvious that today's fossil fuel regime cannot last forever, for the simple reason that the resources will eventually exhaust (or at least dwindle to such an extent that they become exorbitantly expensive). Third, we may be looking at a climate crisis, which is another drawn-out, long-lasting crisis where the immediate impact is not particularly severe, but the long-run consequences are far-reaching. Thus, if peak oil is upon us, not only do we need to compensate dwindling reserves of fossil fuel with something else, but in order to combat global warming, this 'something' else needs to be fairly emissions-free. Thus, while renewable energy is not the answer to all our worries, first it could provide us with new growth industries, second with more energy, and third with relatively *emissions-free* energy. It could go some way to providing solutions to all three crises (obviously renewable energy technologies still have to become cheaper and more efficient). And if we look at how fast renewable energy has expanded, the prospects may not even be completely far-fetched. Since 2000, on average, wind power installations have increased by 24 percent annually, whereas PV (photovoltaic) capacity has increased by an average of 41 percent. In 2000, global wind power capacity was not even 20GW, whereas in 2014 it reached 370GW (see Figure 1.2). For solar, in 2014, capacity reached an estimated 185GW, up from a mere 1.5GW in 2000 (see Figure 1.3) (EPIA, 2014a; GWEC, 2015; REN21, 2014; *SolarServer*, 2015; WWEA, 2014).

But if all this is true, and if renewable energy can potentially be this important, why do we not just install it? Sheikh Zaki Yamani, Saudi Arabia's powerful minister of oil and mineral resources from 1962 to 1986, once famously said 'the Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil' (quoted in Aleklett, 2012, p.121). In his mind, oil would be replaced

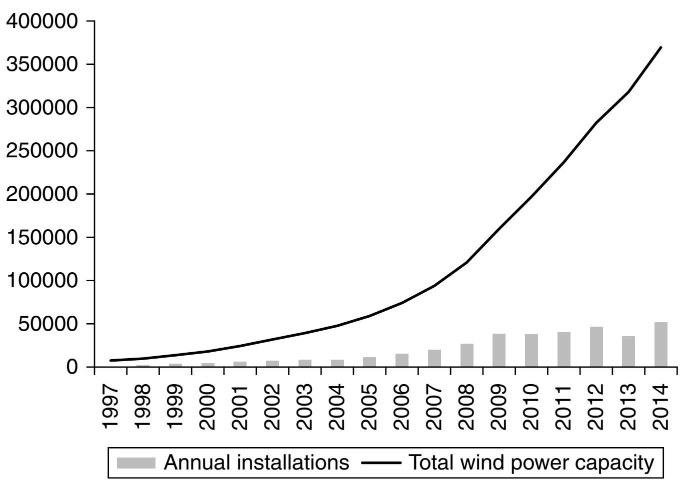

Figure 1.2 Total and annual installed wind power capacity, 1997–2014 (MW)
Sources: GWEC (2015); REN21 (2014).

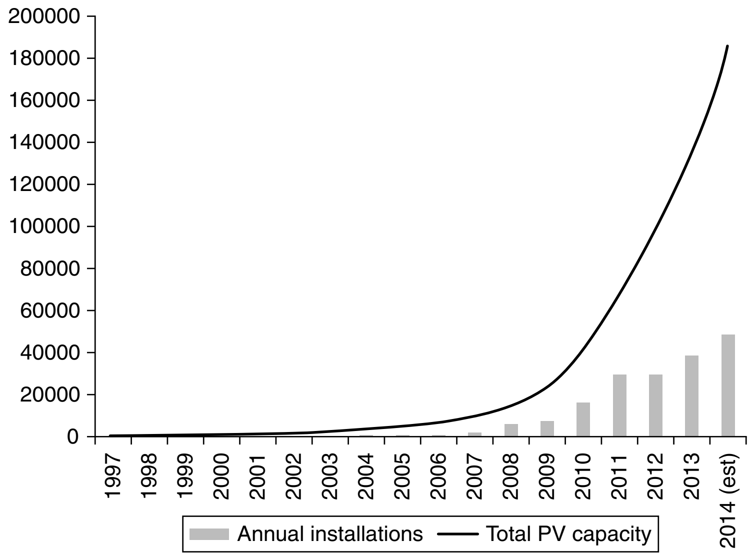

Figure 1.3 Total and annual installed solar PV capacity, 1997–2014 (MW)
Sources: REN21 (2014); *SolarServer* (2015).

by more efficient forms of energy as new and better technologies were invented, and this would occur long before the oil had been extracted. Thus, if renewable technologies were already competitive, the market mechanism by itself would guarantee that renewable energy is fed into the system in such quantities that it makes for an energy transition. One of the goals of this book is, however, to show why this is *not* so, and how in most countries the institutional setup often contains a heavy bias in the direction of fossil fuels. Thus, there is no guarantee that Sheikh Yamani is right in suggesting that this problem will take care of itself. Michael Klare's (2012b) prediction that we are instead facing a race for the planet's remaining fossil fuel resources seems equally prescient. The Oil Age may easily end exactly because we run out of oil.

In a world without learning effects, economies of scale, barriers to trade, institutions, externalities, and so on, markets might easily provide the solution. Markets would then accurately factor in the extra costs deriving from fossil fuels from emitting CO_2 and other greenhouse gases (GHGs), so that all energy industries could compete on equal terms. In such a world, the fact that fossil fuel industries have had far longer to realize economies of scale and to develop mature technologies than most rival energy industries would not be important. However, this is not the world that we live in. Economists can help us compensate for some of the disadvantages that renewable energy industries and technologies face. Carbon taxes would, for instance, go some way toward putting a price on externalities resulting from GHG-emissions. The higher the tax on carbon emissions, the more competitive renewable energy would be, and the more the markets would favor renewables over other forms of energy.

However, ultimately carbon taxes are politically determined, and as such subject to a myriad of concerns. If one country sets its carbon taxes radically higher than other countries, energy-intensive companies may flee and set up shop abroad instead. Also, high energy and electricity prices are bad for the competitiveness of the industry in general, and it is bad for the purchasing power of common people. Thus, introducing, or indeed raising, carbon taxes comes at an industrial and economic, not to say a political cost, and one that politicians are often loath to bear. Doing the right thing for the long-haul is a distinctly bad political strategy if it costs you the next election.

But the lack of a global carbon tax set at an appropriately high level is only one of many reasons why renewable energy is not just replacing fossil fuels overnight. There are other structural constraints as well. Let us breeze easily past the more obvious ones: renewable energy has had far less time than fossil fuels to mature its technologies. Thus, in terms of learning effects, we expect technological progress in renewable energy to be faster than progress in established energy technologies. And in terms of economies of scale, the old and trusted industries have had far more time to realize these than have renewable industries.

The slightly more subtle bias is a political one. Institutional theory tells us that institutions create stability. They are the rules of the game. They lead to path-dependencies, and they act as bulwarks against radical change (e.g. March and Olsen, 1989; North, 1990; Olson, 1982). Consequently, institutional change also tends to occur at a far more glacial pace than technological change. New and upcoming industries frequently have different needs than established ones – in terms of knowledge and education, capital, linkages between academia, government and industry, patenting systems, and so on. The degrees to which these needs are met are crucial. A national system of political economy may be a good fit for one type of technologies and industries, but a distinctly bad one for other (and often rival) technologies and industries (e.g. Freeman and Perez, 1988; Gilpin, 1996; Nelson, 1995; Unruh, 2000). Quoting Gilpin:

> …a society can become locked into economic practices and institutions that in the past were congruent with successful innovation but which are no longer congruent in the changed circumstances. Powerful vested interests resist change, and it is very difficult to convince a society that what has worked so well in the past may not work in an unknown future. Thus, a national system of political economy that was most 'fit' and efficient in one era of technology and market demand is very likely to be 'unfit' in a succeeding age of new technologies and new demands. (1996, p.413)

Thus, if the institutional system heavily favors old and established energy actors over new and promising, but ultimately vulnerable renewable energy actors, then this is something that markets will not pick up on. And so, if renewable energy is among the solutions for the future, energy-wise, industry-wise and climate-wise, the above points represent just a few reasons why markets do not automatically allocate enough resources to renewables. This also suggests why it is necessary to bring in the social sciences. The naïve take on renewable energy would be to simply think of this as a technological challenge, solved by natural scientists and engineers, letting technological progress run its course, and then within hopefully not too long, renewable energy technologies would be so efficient and sophisticated that they can compete on equal terms with fossil fuels.

This is, however, a book on the *political economy* of renewable energy, suggesting that politics and economics are crucial to understanding renewable energy. Obviously this does not mean forgetting that there is a heavy technological component to the rise (or the failure) of renewable energy. Compared to other and more established energy technologies, renewable technologies still have a lot of maturing left before they are anywhere near revolutionizing the world's energy supply. But this takes nothing away from the fact that in addition to technological constraints, there are economic and political constraints affecting the prospects of renewable energy. Few areas are more cross-disciplinary than energy policy.

It is impossible to understand energy policy without understanding the linkages between the technological, the economic and the political. When renewable energy is *not* implemented in a country, this might be for technological reasons. But if we compare the most developed countries in the world, their ability to solve and work around technological obstacles is more or less the same, and so if one country manages to solve its technological problems, most others could follow suit. Then, there might be economic problems, typically as in renewables being too expensive, but many of the economic constraints faced by different countries also resemble each other. And then there are the political problems, and the political constraints, which are often the hardest to penetrate – because politics regularly operates according to a different logic, one that involves stakeholders, vested interests, institutions and institutional biases, as well as path-dependencies and inherited organizational and institutional cultures and quirks that are country-specific and where the experiences of one country cannot always be transferred to any other.

Renewables or bust?

So, are there no realistic or credible alternatives to renewable energy? Is renewable energy so important because it is the only current answer? The answer is not at all straightforward, but let us look at some of the alternatives.

Let us start with the default solution, which is simply more of the same. Granted, whether or not peak oil is upon us, there is no immediate danger. The world's proved oil reserves have kept on increasing, especially if we also take unconventional sources into account, and the current drop in oil prices strongly suggests that the world is not running out of oil overnight. Instead, it is rather a matter of how eagerly we pursue the remaining resources, open up new areas for exploration, the extent to which new technologies can help us in exploiting resources that in the past used to be technologically unfeasible, and the extent to which new technologies can help us to extract a higher percentage of petroleum from existing wells. So, to an authority such as Daniel Yergin (2011) – co-founder and chairman of Cambridge Energy Research Associates and a Pulitzer Prize winner – the world is still awash in oil. We may be approaching a production plateau, but no peak. Reserves have never been greater, and pretty much the same goes for production levels (Yergin, 2011, p.239)![3]

Others are not equally sanguine. Michael Klare (2012a, 2014) – professor at Hampshire College and the author of a number of highly influential books on oil and energy – forcefully states that while it is technically true that we are awash in oil, the days of '*easy* oil' are long gone. Over the next 25 years, 'easy oil' fields will lose 75 percent of their productive capacity.[4] Shale gas, breakthroughs in fracking, deep-sea drilling, and Arctic oil may prolong the petroleum age. But if the future were to be still fueled by petroleum, every pretense of this being a cheap and abundant source of energy must surely be abandoned. Scarce and expensive energy will also keep jeopardizing the growth prospects of the world economy.

Peak oil has been predicted before. In 1956, Marion King Hubbert, who coined the term, predicted that US oil production would peak between 1965 and 1970, in 1962 he suggested that world oil production would peak in 2000 and in 1974 that the peak would be in 1995. Numerous others have also engaged in this activity, but so far, the doomsayers have been proven wrong. Production today is twice of what it was in 1970 and more than four times of what it was in 1960. The present consensus times peak oil to some time between 2010 and 2030, with oil production definitely declining after 2050 (Aleklett, 2012; Chapman, 2014; Sorrell et al., 2010). Yet, while reiterating the lack of any immediate danger, demand for oil does keep increasing, and very few new giant fields are discovered anymore. It is not that the rate at which we find new oil fields has dropped dramatically, but the size of these fields are now significantly smaller than a few decades ago. In 1960, a record 60 new gigabarrels of oil were discovered. By 2010, this had dropped to only ten. Since 1980, oil consumption has exceeded oil discoveries every year except for two. The world presently consumes approximately 87 million barrels of oil per day (mb/d). Demand is projected to rise to 101mb/d by 2035, at which time *conventional* crude oil production may have fallen to 65mb/d. The in-between volume will have to be covered for by unconventional oil and natural gas liquids (Aleklett, 2012; Ayres, 2014; Energimyndigheten, 2006; IEA, 2013c).

Can this be done? After years of strong growth, these are somewhat testing times for renewable energy, its prospects not as certain as only a few years ago. Part of the reason for this is the breakthrough in fracking that in the US has led to a potential revolution in shale gas and tight oil. This could be a game-changer. In 2012, the IEA confidently predicted that by 2020 the US will be the world's largest petroleum producer, overtaking Saudi Arabia and becoming a net petroleum exporter. This is a major turn of event. In 2013, the US surpassed Russia as the world's largest *energy* producer (Blackwill and O'Sullivan, 2014).

Thus, in the US, tight oil production increased 18-fold between 2007 and 2012, almost doubling overall US oil production, whereas shale beds account for more than 50 percent of natural gas, up from only 5 percent a few years ago. The fresh supply of shale gas led to US gas prices dropping from $12/million Btu in 2009 to less than $2 in 2012. In the US, the immediate consequence has been for coal to be substituted by natural gas, which has reduced GHG-emissions in the US. The other consequence is to render renewable energy far less competitive. In 2012, which was a breakthrough year for US shale, shale gas led to a decrease in renewable US energy investments (EREC, 2013). The impact on natural gas prices is local, not global. In Germany the price stands at $11/million Btu, and in Japan it has been as high as $17. In other words, outside of the US, the competitive pressure on renewable energy is less. On the other hand, the US preference for natural gas over coal means that the US now ships far more of its surplus coal (US coal exports to Europe increased by 29 percent in 2012) to Europe, where coal prices immediately dropped by a third. Thus, in Europe, coal has replaced liquid natural gas (LNG) (*Financial Times*, 2013), and the main reason why in Germany coal keeps *increasing* its share of energy and electricity production at the expense of natural gas is that the shale revolution makes coal less desirable in the US – where its relative price has increased – but more desirable in Europe, where its relative price has fallen. Europe is now 'an unfortunate mirror image of the US' (*energy post*, 2014).[5]

For us, the crucial question is, however, whether or not shale can be the energy answer for the future. Is it a credible alternative to renewable energy? Does the shale revolution push any notion of peak oil into an indefinite future, or does it just breathe some extra life into an already waning energy paradigm? The answer depends very much on who you listen to. In 2012, President Barack Obama made a bold claim that the US has enough natural gas to last a hundred years. *Time* (2013), in 2013, declared that peak oil is dead. *Business Insider* (2013) stated that 'we have slayed "peak oil" once and for all, thanks to the combination new shale oil and gas production techniques and declining fuel use.' *The Wall Street Journal* (2012) ran a piece simply titled 'Saudi America', on how the US would soon become the world's largest oil producer – if it only frees itself from the shackles of environmentalists demonizing anything that smacks of carbon energy. From the petroleum industry we hear that the US has the petroleum fracking resources of two Saudi Arabias. And both the IEA and the US Energy Information Administration (EIA) have been very bullish about US resources, and how this could completely alter the world's energy situation (*GlobalResearch*, 2014; Heinberg, 2013).

This bullishness is giving way to more sober assessments. IEA (2013c) now says that tight oil will have a major impact over the next decade, but not in the long term as the US will reach a plateau over the next decade. The EIA has made very drastic downward adjustments to their estimates of recoverable oil. Their current estimate for shale gas is for 24 years of supply at current rates, with other estimates as low as ten years. The main problem is that production at the wells typically drops off by 60–90 percent in the first year of production alone and 80–96 percent during the first three. Thus, merely keeping production at current levels requires evermore drilling at ever higher costs. The US can keep doing this for a while, and there is undoubtedly much life in the industry, but there is also little doubt that the industry has a vested interest in perpetuating the image of shale as the way forward and as the wonder fuel of tomorrow. US petroleum and drilling interests have very deliberately sought to urge US energy policy in the direction of shale (Ayres, 2014; Heinberg, 2013; *LMD*, 2013; *Los Angeles Times*, 2014; *Power*, 2014f).

It is also not obvious that this is a good move even for the US. The break-even point for shale gas is estimated at somewhere between $4 and $8/million Btu, and currently the industry is losing money. The top shale gas producers are taking heavy losses and have large debts, and the recent oil price fall is threatening the profitability also of a number of tight oil producers. Thus, without gas prices increasing (and possibly also the oil price), the shale revolution will be stillborn not only because the wells deplete but also because it is not profitable (EREC, 2013). Thus, this is not presently a moneymaker for the US or for the US petroleum industry. Also, for shale to be a worldwide revolution, it would have to spread to other countries. There are limited prospects within the EU. With the exception possibly of Poland and Ukraine, where reducing energy dependence on Russia is the biggest concern, Europe seems highly reluctant. European public opinion prefers renewable energy over shale and the EU Commission has noted how shale gas causes higher GHG-emissions than conventional natural gas.[6] China, which has the world's largest reserves, does indeed have a shale development plan. But there are major impediments to large-scale production. Chinese coal seams are deeper and less accessible than US seams (which have mostly been found at shallow depths), and fracking requires large amounts of water, which is a far scarcer commodity in China than in the US. Thus, China is still essentially on the fence, and production goals for 2020 have been slashed by more than 50 percent (*Economist*, 2014f; Hu and Xu, 2013; *theenergycollective*, 2014b; Wan et al., 2014; Wang et al., 2014). The jury is still very much out on the potential of shale, but even at present rates of production, shale has definitely made an impact. If it were to be a true energy revolution, this would be bad news for renewable energy, even if so far in the US, it has led mostly to the substitution of coal.

Nuclear power is another X-factor. The nuclear revolution never played itself out to the full. Nuclear has never provided more than 5 percent of the world's total energy supply and has dwindled in popularity since Chernobyl. And as the world was again starting to feel safe for nuclear, Fukushima happened. Fukushima led to Germany giving up on nuclear overnight and to Japan losing its entire nuclear power capacity. However, for Japan, the absence of nuclear, and the only gradual expansion of renewables, for all practical purposes makes it impossible to fulfill Kyoto commitments as the energy gap is made up for by massive LNG imports, and for Germany, renewable energy is just about capable of compensating for the power loss from nuclear, but this also means that the fossil fuel share of energy and electricity production remains more or less unchanged. In the meantime, other countries are increasing their nuclear capacity. Worldwide 62 new reactors are built, most in China, which is adding 26 reactors to its present 16. Thus, both for energy and climate reasons, nuclear will stay with us. Indeed, Fukushima has showed us how much more difficult combating global warming will be if it were to coincide with a nuclear phase-out. Still, even the major Chinese expansion will hardly bring the share of nuclear in Chinese electrical power generation above 10 percent by 2030, thus what we are witnessing is no nuclear energy revolution. Actually, renewable energy in China expands faster. In 2012, total wind power output for the first time exceeded nuclear power output (Andrews-Speed, 2012, p.50; REN21, 2013a; *TU*, 2012a). Thus, while some countries are expanding their nuclear capacity, nuclear is not the answer to our questions. The IEA (2013c) expects nuclear power to maintain its share of electricity generation worldwide, which means around 12 percent, but not go beyond that. Also, if nuclear were to start expanding at a rate that would actually make a major difference to the world's energy supply, then it is not apparent that our deposits of uranium would last much longer than the petroleum.

Finally, and most depressingly from a climate perspective, coal keeps expanding. This is mostly because of China, which in 2011 accounted for 87 percent of the world's increase in coal consumption, and whose demand for coal is expected to continue to rise until reaching a plateau no sooner than 2025. But as mentioned, because of shale, coal is on the rise in Germany as well. Granted, this rise is not expected to be permanent, but it does bear witness of an industry that is not prepared to give in. The coal industry is also among the most powerful vested interests in the US. Thus, in terms of global primary energy demand, by 2035, the share of coal will not have changed much. In its 'New policies' scenario, the IEA (2012b) suggests that coal's share will fall from 28 to 25 percent. However, in their default scenario, it instead increases to almost 30 percent. Carbon Capture Storage could be a solution. However, the IEA (2013c) reckons that by 2035 only 1 percent of all fossil fuel fired power plants will be CCS-equipped. Despite the deleterious effects of coal on GHG-emissions, unless policies radically change, there will be no major phase-out in the near future.

Is renewable energy the answer? And, if so, what exactly is it the answer to? According to all predictions and projections, energy consumption will keep rising. No doubt, technological progress will also result in major energy efficiency improvements, but, so far, there is little indication that this will lead to energy consumption actually falling. Thus, it is not very controversial to expect that we will only need more energy. Conventional oil and gas will hardly be able to expand much further. Even if no peak oil is imminent, petroleum extraction will drop rather than increase. Shale gas and tight oil may pick up some of the slack, and the potential from Arctic oil and deep-sea drilling is hard to estimate. But with both the IEA and the EIA holding far more sober assessments of the prospects of shale gas and tight oil than only a year ago, and since Arctic oil and deep-sea drilling will be costly no matter, it is hard to see much actual *growth* in energy production stemming from petroleum. Based on present knowledge, it is also hard to see nuclear ever getting the renaissance that will make it the answer to our energy prayers if not for major breakthroughs in thorium. And, despite technological improvements and the potential introduction of CCS to coal power plants, most policymakers are hesitant about coal as the energy solution of the future. Even coal with CCS is not an environmentally friendly solution. Retrofitted to existing plants it would obviously be an improvement compared to the status quo, but *new* coal plants with CCS would not be.

This leaves us with renewable energy. Granted, as compared to the 87mb/d of oil that we currently consume, the amount of power produced by wind is the equivalent of roughly 2mb/d and by PV only 0.4mb/d (Jaffe and Morse, 2013). When President George W. Bush talked about the American oil addiction, his major solution was biofuels. But most likely biofuels will never be more than a small player, especially as the consequence of increasing our production of biofuel would seriously take away from our ability to produce food. Turning the whole crop of US maize into biofuels would, for instance, not amount to more than 5 percent of US oil demand (Chapman, 2014). Thus, policymakers are far less sanguine about the prospects for biofuel than only a decade ago. And the oldest of all renewable energy technologies, hydropower, still has much life left in it, but beyond developing countries, the potential for expansion seems limited. Geothermal, wave energy, and other types of renewable energy have considerable potential, but, at present, these rely on far more immature technologies than solar and wind. For the foreseeable future, and as long as no wonder technology suddenly appears out of the blue, solar and wind power will be the backbone of the renewable energy drive, and they will be the energy sources most likely to have the ability to provide a boost to this world's energy production. Can they transform the world of energy? Or are they doomed to remain bit players in a world that stubbornly persists with fossil fuels? Within the world of renewable energy we see both success stories and relative failures. This book is an attempt to distinguish the successes from the failures. Why did some countries pursue renewable energy with so much more enthusiasm and dedication than others? What has been the key to their success? While the answer may not directly tell us whether or not the world's energy structure can or will be transformed, it will say something about whether or not some of the leading economies in the world (as well as some smaller ones) will forge ahead and lead this process, or whether the prospects for a worldwide energy transformation are rather gloomier.

The story, the argument, and vested interests

In order to shed light on why renewable energy is promoted by some and not by others, what we need is an understanding of the underlying drivers of the political economy. Thus, when in this book I look at the renewable energy policies of six countries – Japan, China, the US, Germany, Denmark, and Norway – this is not supposed to be a book only about six specific countries. Rather, the general aim is to say something systematic about the political economy underpinning the growth (or the lack thereof) of renewable energy.

Thus, what this is *not* is a book on present energy and/or environmental policies in a select group of countries, or a review of policy changes over a certain number of years. This already exists. By all means, in this book you will obviously find information about concrete policy actions and changes. However, what to a far greater degree is missing from the literature is information on the more general political economy of renewable energy policy, for two reasons, I think. First, the literature on renewable energy has been dominated by natural scientists. Obviously, one should not be surprised that natural scientists have a better grasp of technological matters than social scientists, but it inevitably leads to a discourse centered on technical problem-solving, ignoring the economic and political aspects of renewable energy policymaking. Second, to the extent that social scientists *have* focused on energy issues and renewable energy, their accounts have tended very much toward the description of policy measures and policy initiatives. Instead, in order to gain a firm grasp of the underlying drivers of renewables, we need to recognize that today few areas are more cross-disciplinary, and that it is impossible to understand energy policy without understanding the linkages between the technological, the economic, and the political.

Thus, this is the story of a Japan where energy policy has been gridlocked by strong vested interests for four decades, but where Fukushima has forced the most serious re-think to energy policy for that entire time and overnight has led to a booming solar PV market. It is also a story of a country that both before and after Fukushima has systematically opted for PV to the detriment of wind power, which has been sorely neglected. It is also the story of a China where the renewable expansion has been faster than anywhere else, and where the sky seemingly is the limit, but where there are still potential clouds on the horizon, albeit clouds that by many are ignored because impressive growth is keeping everyone happy for as long as growth persists. It is the story of a US which has endured more, as well as more pronounced, policy swings over the past four decades than any of the other countries, and where renewable energy policy to a very small extent has been institutionalized. The US story is also about a legislature that gridlocks easily and which has readily fallen prey to the influence of vested interests, making it difficult to pursue more than incremental change. Germany is the story of a country where a very robust social and political consensus on environmental protection, nuclear phase-out and renewable energy early on led to the development of a strong renewable energy coalition, which enabled such a rapid phase-in of renewables that no country has so far installed more solar PV. But it is also the story of a country that was so successful in phasing-in renewables that eventually subsidies became so expensive that the entire renewable support structure has had to be restructured. Thus, the German story now has a more open-ended future than most would have foreseen only a few years ago. This is also the story of Denmark, which grew to become maybe *the* iconic wind power country. With the greatest wind turbine density in the world and the world's biggest wind turbine manufacturer in Vestas, Denmark has had one of the most stable support frameworks for renewable energy and derives more of its electricity from wind than any other major country. And, finally, it is the story of Norway, which unlike the five others, is an energy-exporter rather than an importer. Norway is the world's third largest energy-exporter and in addition to petroleum has an abundance of hydropower. Thus, the Norwegian story is a story about how renewable energy has fared in a country that is highly energy-secure and has very strong vested interests with respect to petroleum extraction. Consequently, it is also a story about a country where wind and solar power have so far been sideshows and window-dressing.

On a more general level, this is the story about the political economy of renewable energy, and about why some countries so much more enthusiastically pursue renewables than others. One default expectation would be to simply assume that the ambitiousness of a country's renewable energy policies mirrors the seriousness of its energy problems. Thus, countries with unsolved energy problems (or an abundance of renewable energy resources) ought to have more ambitious policies (e.g. Eikeland and Sæverud, 2007). This book, however, suggests that there is far more to the story.

Thus, this book suggests that this is also the story about how vested interests bias political decision-making and wrest away from the state the autonomy to independently pursue policy. Strong vested interests for instance make it difficult for a Norway which has become wealthy by exporting petroleum to change its energy-political course. Decisions are often biased in the direction of the most powerful interests. Likewise, for a country that is scarce in energy resources, and with only weak vested energy interests, it is far easier to initiate renewable energy programs and support structures, as there are far fewer interests to oppose this.

Why are vested interests a problem? Here I suggest two answers: one immediate and one more long term and fundamental. The short and immediate answer is derived from the economic historian Joel Mokyr (1990). Through history, vested interests have always protected themselves by seeking to block structural change, technological progress, the rise of challenger industries, and so on. In his book *Lever of Riches*, Mokyr outlines three mechanisms through which this has historically happened. First, there is outright physical resistance against new technology, as in strikes, riots, and even the destruction of new machinery. Second, opposition has taken the form of laws and regulations restricting the implementation of new technology and erecting barriers of entry, such as guild systems, trade unions, labor unions, lobby groups and state monopolies. And third, vested interests have shielded themselves against competition and change by pushing through protection and favorable treatment, such as tariffs and subsidies.

Thus, vested interests have a number of ways in which they, for all practical purposes, block the rise of rival industries – which in this book means renewable energy industries. Renewable energy industries and technologies have to rise against an economic and industrial backdrop dominated by old and influential energy interests. Granted, the old and established interests may not actively seek to make life hard for renewables; however, as they fight for their own interests, for regulations, subsidies, favorable institutional arrangements, and so on, they often invariably do this at the expense of renewable energy. As Gilpin (1996) makes clear, new and upcoming industries frequently have different requirements than the old and established industries, and thus the needs of coal, petroleum, or nuclear often come at the expense of the needs of renewables.

The second answer is more fundamental and centers on what it is that fuels the world economy. At the core of economic growth lies technological progress.[7] True, there are many types of economic growth. Thus, privileging growth based on technological progress does not mean that other types are unimportant. To return to Mokyr (1990), Solovian (after the US economist Robert Solow) growth is investment-led. This is the kind of growth that we get whenever the capital stock accumulates faster than the labor force. Smithian (after Adam Smith) growth is based on commercial expansion, or gains from trade – a more specialized division of labor leads to productivity growth. And third, there is growth based on scale or size effects. Finally, growth based on increases in the stock of human knowledge, innovation, and technological progress – or Schumpeterian growth (after the Austrian economist Joseph Schumpeter) – is, however, different in one signal way, namely in that it does not lead to diminishing returns. Investments, trade, and scale are all important, but you do come to a certain point where the investment rate for all practical purposes cannot be raised much higher, where world trade cannot be made much freer, markets cannot grow much bigger, where larger scale does not provide much of an extra benefit, and where further specialization cannot grow much more extreme; in other words, where the extra effort yields very small extra gains, or diminishing returns. With technological progress this is not so. One could, of course, conceive of a world in which technological progress came to a halt because there was essentially nothing left to invent. If so, technological progress would experience diminishing returns as well. However, there is no indication that this is happening. As long as technological progress occurs, and for as long as mankind keeps inventing, no diminishing returns will set in. Britain, and in general the Western world, saw growth slowly accelerate from the late 18th century onward as a consequence of industrialization, and from technological progress feeding on and reinforcing further progress, with innovation leading to more innovation. Trade, markets, and the division of labor were obviously important, but what revolutionized the way in which the world economy works, and which led to steadily increasing growth rates, was the new and unprecedented speed of technological change. Thus, if Schumpeterian growth were to slow down – if the future were to be a future in which technological progress came to a stop – the growth engine of the world economy would also grind to a halt.

What this also means in terms of our roundabout and long-term answer to why vested interests is a problem is that this is a story about structural change. Technological progress is the main driver of structural economic change. Structural change is essential for long-term growth and development. In one sense this is utterly trivial. Without it, we would all still be hunter-gatherers, or farmers and fishermen, or industrial workers. The industries that power the world economy of today are not the ones that did the job two centuries ago. It would be naïve indeed to expect the cotton textiles industry of the early industrial revolution to still be the primary driver of growth today. Similarly, structural change within the energy sector means that there are few similarities between the energy technologies that power our present-day industries and those of the early Industrial Revolution.

In another sense, it is not at all trivial. Structural change is what makes a country leap from one economic trajectory to another. It typically stems from breakthrough technological change, resulting in the rise of new industries that eventually end up serving as the growth engine of the economy for decades ahead. In textbook economic theory, whether you make a billion dollars from microchips or from potato chips makes no difference. The stimulus to the economy is the same. If instead you believe in the importance of structural change, it *does* make a difference. Making a billion from microchips is far better, because it provides productivity improvements to a whole host of different industries and gives rise to entirely new economic activities. This is what produces growth, not just in the present, but in the long run.

The world has gone through several such industries, and a number of successive waves of industrial revolutions. Empirically they have lasted for 50–60 years before saturating and giving way to new waves of growth based on new growth industries. Different scholars tell different versions of the story, but the basic elements remain the same. Thus, the economic history of the world can be described as one of core industries based on new and generic technologies serving as engines of economic growth during different historical epochs, starting with cotton textiles in the late 18th century, iron in the early 19th century, chemicals in the late 19th century, consumer durables in the early 20th century, and finally industries based on information and communication technologies (Freeman and Perez, 1988; Modelski and Thompson, 1996). The transition between these waves is, however, often not smooth. The waves are driven by the growth of one or a few leading industries. These industries first rise from obscurity to economic prosperity over a fairly short period of time, then mature, and toward the end of the product cycle they saturate, as it becomes ever harder to find new avenues of growth. As they saturate, the world economy drifts into a structural depression that is ultimately only resolved when new (generic) growth industries provide the economy with a new industrial engine. Paraphrasing Schumpeter, the world economy goes through 'waves of creative destruction' (Schumpeter, 1942; 1983). Depression destroys old firms and industries, but it also leads to the creation of new ones.

But as suggested above, creative destruction does not necessarily happen by itself. Instead, in any economy, there are strong forces that seek to prevent structural change and preserve the status quo. The logic is not particularly complicated, and can be found in, for instance, Mancur Olson (1982). As an economic sector becomes economically prosperous, it typically also becomes politically more influential, securing arrangements and institutions that are beneficial to itself rather than to the economy at large. Thus, institutional stability leads to institutional rigidity when vested interests attempt to preserve the institutional status quo that worked so well for them in the past. The more a country depends on one or a few industrial clusters, and the greater their dominance, the more likely that the state grants them the institutions and the arrangements that they desire. If the economy is controlled by vested interests, it loses its ability to change, adapt, and shift the status quo. Thus, when industrial and structural change does not happen by itself, despite the availability of new technologies, it is because of a whole vested interest *structure* protecting and sheltering the existing actors of the system.[8] There is no such thing as a level playing field. Politically, economically, and institutionally the established actors hold all the advantages.

Thus, new industries often find themselves constrained by vested interests using their influence to sway policy decisions in their favor. This is not such a big problem in an economy that is open to structural change and where technological progress is allowed to persist. But when the process of creative destruction is blocked, this inevitably leads to the silting up of institutional rigidities in the political economy. As a consequence, new and vulnerable industries easily end up in a situation where they are blocked by a political and economic structure that favors the old and established actors of the system. For new industries to rise in the presence of long-established and powerful rivals, they will need some form of backing.

By now, this long and roundabout answer is hopefully making the importance of vested interests a little clearer. These are processes that have taken place at least since the start of the Industrial Revolution (probably longer), and will keep materializing, pretty much irrespective of the industry. Now, if we move our focus away from industry and toward energy instead, we immediately see that the energy history of the world resembles the industrial history, with energy transformations mirroring the structural changes in the industrial economy. For at least the past quarter of a millennium there has been a symbiosis between energy and industry. There is a strong and well-documented correlation between energy and long-term economic growth and development (Ayres, 2006, 2014; Freeman and Perez, 1988; Smil, 1994, 2003). There is little doubt that steam power, electricity, and oil have been essential to long-term growth processes. Industrial waves would not have appeared if they had not been supported and accompanied by the discovery and rapid exploitation of a new source of abundant energy – a new resource. And through technological progress, this resource has then rapidly become more exploitable and a lot cheaper. Without new sources of energy, structural change and renewed growth in core industries would have been more or less impossible. Equally importantly, without technological change and industrial progress, there would have been little pressure to find and develop new sources of energy.

Thus, the early industrial revolution was powered by water, which then gave way to coal and steam power. Electricity revolutionized the world of energy from the late 19th century onward, and since the early 20th century, petroleum has been the life-blood of the world economy. Nuclear power was a stillborn energy transformation. Many thought of nuclear as the new miracle energy of the post-war era, but a number of accidents – Chernobyl, in particular – and problems with the storage of nuclear waste have confined nuclear power to no more than 5 percent of the world's energy supply. And the latest and most tentative and potential of all energy transformations is the one that we still have ahead of us, a low-carbon transformation entailing a shift away from the current fossil fuel paradigm and toward something based instead on renewable energy.

Such a transformation would be truly momentous, and the forces working against it are among the most powerful and influential that any new industry has probably ever faced. Energy companies are the world's biggest industrial giants. Of the world's ten largest companies (total revenue), five are fossil fuel providers, one is an electricity company, two are carmakers, and one is a mining company (*Fortune*, 2014).[9] These are companies that wield enormous political influence, companies that invariably have the policymakers' ear, and companies that have had the necessary time and resources to secure for themselves favorable institutional setups and regulatory arrangements. As these are old and mature industries and technologies, typically the kind of innovation that flows from these is incremental rather than transformational and disruptive. Very often it feels like the 'safe' choice for policymakers to offer continued public innovation support for mature technologies and industries. But that also means that governments invariably send out the signal to investors that capital will keep accruing to old technologies rather than to new basic innovations and potential transformational and disruptive technologies. And so, in so many countries, there is a strong institutional bias in favor of the present energy structure, based on fossil fuels (and sometimes nuclear) and on big, centralized energy utilities distributing electric power to a vast number of industries and households. Unruh (2000) labels these *techno-institutional complexes* (TICs). They are large technological systems embedded through feedback loops between technological infrastructure and institutions. Once locked in, they are not easily replaced. Today's petroleum companies are the biggest industrial giants on the planet, part of a TIC that perpetuates a fossil fuel based infrastructure, exacerbated by government subsidies and institutions, and resulting in what he calls a 'carbon lock-in'. It typically takes political action beyond mere market mechanisms to displace a TIC and implement a new energy structure.

If renewable energy were to emerge as the energy of the future, replacing fossil fuels, this would constitute one of the biggest structural changes ever in terms of energy production and supply. Its rise is in no way guaranteed. Especially since for it to happen, it would have to rise against a locked-in energy structure populated by the world's biggest industrial giants, actors that have had years to influence the system that they are an intrinsic part of. This means that whether renewable energy is the next big wave or not, what we need to analyze are the vested interest structures of countries, their path-dependencies and the extent to which they are seriously and actively pursuing policies of structural change. An analysis of renewable energy that takes the international political economy as its starting point thus has to do two things: It has to take into account the linkages between technology, economics and politics, explaining the rise (or the absence) of renewables in terms of the underlying dynamics of the political economy of a country. But it also has to realize that a proper treatment of renewables means inscribing it in a political economy tradition focusing on structural change, with renewables as only one of, through history, a series of industries and/or energy providers that have had transformational potential on the world economy.

Vested interests are obviously not the sole valid vantage point for an analysis of the political economy of renewable energy. Clearly, a number of factors affect the chances of renewable energy. But by focusing on vested interests, or on vested interest structures, what we have is an angle that points us in a very specific theoretical direction, but without ever becoming a theoretical straitjacket. It hones in on certain aspects of the political economy worth analyzing, but still the notion is empirically open to the extent that it lets us look at institutions (through which vested interests often operate), different economic and political actors, interest groups, the political and economic discourse, and so on. In other words, much of the work has to be done inductively, as in investigating the extent to which political elites have been receptive to the needs of renewable energy, or if these industries have instead been at the mercy of policies designed to protect the interests of older and more established energy interests against a change in the status quo. And it has to be done inductively as in mapping the relevant interest groups in each country and extent to which they were successful in influencing policy. This also means that the theoretical framework of this book can easily be adapted to the specific circumstances of individual countries, and it allows us to respect the fact that there may be major country-specific variations in renewable energy policies that can only be understood by studying that country more closely.[10]

The case for renewables and the state of the renewable realm

The chapters in the book reveal the stories of Japan, China, the US, Germany, Denmark and Norway. All of the chapters contain quite a few numbers and statistics, as in how much wind and solar power has been installed, how rapid growth has been, and so on. While the story I am telling is not primarily a quantitative one, descriptive statistics obviously still provide us with important clues as to how ambitiously a country is promoting renewable energy. Thus, in this chapter I am pulling some of these facts and figures together. It may disrupt the flow of the story, but there should be at least one place in the book where the reader can fairly easily get a quick overview and some hard and fast knowledge of the status of renewable energy rather than having to sift through every specific country chapter, looking for the same information.

Let us start by saying that there are a number of reasons why renewable energy has major growth potential. It is obviously hard to know for sure if it will constitute *the* growth wave of the future. This is a story of Schumpeterian growth, and Joseph Schumpeter himself – maybe as a result of his not particularly happy memories as finance minister of Austria in 1919 – was inherently skeptical about the ability of politicians to pick industrial winners (McCraw, 2007). To Schumpeter, politics too often became business, with politicians essentially reduced to utility-maximizing political entrepreneurs searching for 'policy innovations' to satisfy particular interest groups and voters, rather than working for the country as a whole. Trying to win the political game, so as to remain in power, becomes priority number one.

While Schumpeter's skepticism against picking winners was a healthy one, there are, however, some things that we can say about the future with quite a lot of certainty. And so, whether renewable energy constitutes the next big wave or not, whether it will replace fossil fuels or not, and whether or not it leads to anything resembling an energy transformation, it certainly constitutes a cluster of highly interesting and promising industries that are bound to have decades of technological progress and prowess ahead of them. There are a number of reasons for this, but most obviously and fundamentally, for the first time in human history, we are starting to bump up against the planet's physical limits. True, environmental problems have been serious and commonplace in the past too (such as the London smog), but these problems were rarely more than regional, and could always be solved in one way or another (e.g. by building taller chimneys). But our problems are now becoming global. This has manifested itself in two very concrete ways: (1) Oil prices have skyrocketed (despite their recent drop), and (2) human-induced global warming has become an accepted scientific fact. While the attempts at creating frameworks to replace the Kyoto Protocol have been distinctly underwhelming, one would assume that domestic and international framework conditions are likely to yield more rather than less stringent regulations on polluting industries. And that increased renewable energy production will be part of the effort. For fairly obvious reasons, industries that can provide energy without releasing greenhouse gases and industries that reduce the energy consumption should only become more competitive.

In the short term, renewable energy will not replace fossil fuels. This would require growth on an unprecedented scale over a much extended time span. In addition, neither sun, wind (apart from under very favorable conditions), nor other types of renewables bar hydro, are able to compete on price with fossil fuels, yet. While fossil fuel prices are more likely to increase than to drop, chances are that renewable energy still has a long way to go before it can claim to be either cheap or abundant.

That said, there is an abundance of evidence testifying to the strong growth of renewables. While starting from a very small base (1.2 percent of global final energy and 3.6 percent of electricity production as of 2013), growth figures are impressive. As mentioned earlier, wind power capacity has grown by an average of 24 percent annually since 2000 (although slowing down), and solar PV by more than 40 percent. Over the past eight years, PV has grown by more than 50 percent a year. So, for a while, driven at least partially by the massive fall in costs for PV cells and modules, PV has seen extreme growth. For the past few years roughly half or more of the new electric capacity installed worldwide has come from renewable energy (in 2013, 56 percent of the net additions to global power capacity were renewable). The EU is the front-runner. Here, in 2013, for the sixth year running, renewable energy represented more than 50 percent of new electric capacity. In 2013, the figure was as high as 72 percent. Compare this to only a decade ago, when fossil fuel generation accounted for more than 80 percent of annual capacity additions, and it is easy to see that while still small, in the European electricity markets, renewable energy is making major inroads. In the US as well, in 2012, approximately half of all electricity capacity additions were renewable (although not in 2013, as politics led wind power to have a particularly bad year – more on that in the US chapter (Chapter 4)). Granted, a lot of the capacity is hydropower; of the world's total renewable power capacity of approximately 1600GW (2013), hydropower accounts for more than 1000GW. Of the remaining third, as of 2014, wind power capacity is 370GW and solar an estimated 185GW.[11] Thus, wind power has by far been the more popular. However, in 2013, for the first time, more solar PV capacity (39GW) was added worldwide than wind power capacity (35GW), something which may easily continue (EPIA, 2014a; GWEC, 2015; REN21, 2013a, 2014; *SolarServer*, 2015).

China is the world leader in terms of total installed capacity – approximately 145GW of non-hydropower renewables. The US is second with 86GW and Germany third with 77GW. Japan has a little over 27GW, Denmark 5GW, and Norway less than 1GW. On wind power, Germany held the lead until being surpassed by the US in 2008, with China moving ahead of the US in 2010. At the end of 2014, Chinese capacity was listed at 115GW, the US at 66GW, and Germany at 39GW. Denmark has almost 5GW, Japan 2.8GW and Norway around 850MW (see Figures 1.4 and 1.5) (Burger, 2015; GWEC, 2015; *pv magazine*, 2014b; *SEIA*, 2015; *Vindportalen*, 2015). Between 2005 and 2010, China, for all practical purposes, doubled its capacity every year. It should, however, be added (see also the China chapter (Chapter 3)) that the Chinese figures are somewhat inflated as up to a third of the Chinese capacity is not grid-connected, and that the US actually produces more TWh of electricity from its 66GW than China does from its 115GW (AWEA, 2015b). Growth in the US has also been brisk, but characterized by violent swings. For instance, in 2012, both China and the US installed 13GW. In 2013, however, China installed 19GW, in contrast to only a little over 1GW in the US (which then returned to around 5GW

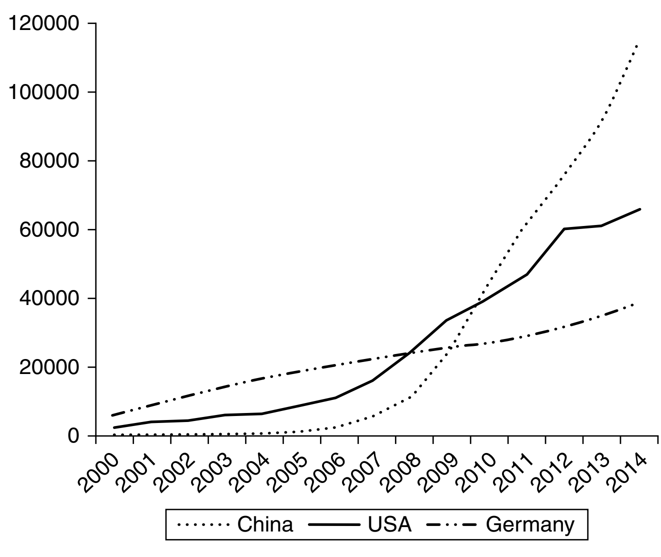

Figure 1.4 Total wind power installations in China, the US, and Germany, 2000–14 (MW)

Sources: GWEC (2014, 2015); REN21 (2014).

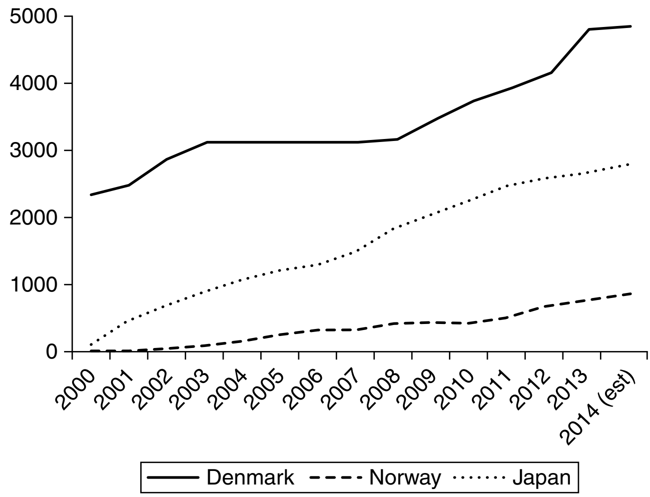

Figure 1.5 Total wind power installations in Denmark, Japan, and Norway, 2000–14 (MW)

Sources: GWEC (2014, 2015); *Vindportalen* (2015).

in 2014). Germany in comparison installs a fairly steady 2–3GW a year. Offshore wind is still tiny compared to land-based wind. As of 2014, worldwide capacity was less than 9GW, almost all of which in Europe. Great Britain accounts for more than 50 percent of this with Denmark in second place and Germany third, both with around 1GW of capacity. China, despite ambitious plans, still has less than 0.7GW, as compared to its 115GW of land-based wind (GWEC, 2015; REN21, 2014).

In solar PV, Germany is ahead of the rest in terms of installations with 38GW, due to very strong growth between 2010 and 2012, but growth which has now been reined in for cost reasons. China is second with an estimated 30GW, but with what is now the biggest solar PV market in the world, China should soon surpass Germany, maybe already in 2015, and most certainly by 2016. Japan has approximately 25GW of capacity, the US 20GW (see Figure 1.6), with Denmark a little over 0.5GW, and Norway practically nothing. Lately, the Chinese, Japanese, and US markets have all grown very strongly, and are now clearly bigger than the German market. With the energy reforms passed by the German Bundestag in 2014, its market is now restricted to 2.5GW annually. In 2014 the Japanese and Chinese markets both installed around 10GW, with the US on 8GW, but most likely growth in Japan will taper off,

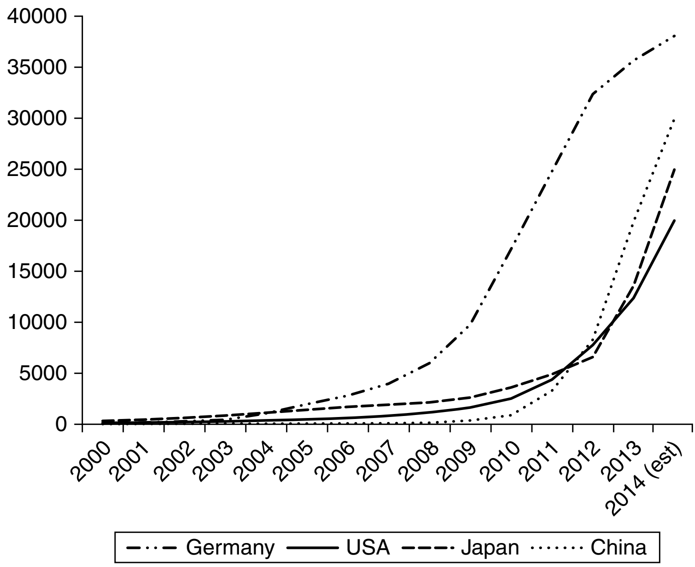

Figure 1.6 Total solar PV installations in Germany, the US, Japan, and China, 2000–14 (MW)

Sources: Burger (2015); EPIA (2014a); GWEC (2015); *pv magazine* (2014b); REN21 (2014); *SEIA*, (2015).

leaving the Chinese markets as the world's biggest (Burger, 2015; *pv magazine*, 2014b; REN21, 2014; *SEIA*, 2015).

The figures provided above testify to very strong recent Chinese growth, and most likely China will soon be the runaway leader, here as in wind. But it is obviously not fair to compare these countries only in terms of total capacity. China is more than 200 times larger than Denmark and has a population 250 times bigger, and so it would be rather odd if it was also not ahead in terms of installations. Thus, if instead we look at wind power installations per capita or per square kilometer, Denmark is the frontrunner, whereas on solar, Germany is far ahead. In per capita or per square kilometer terms, China and the US do not look equally impressive anymore.[12] (Denmark, with its rather scarce solar resources also has more solar capacity per capita and per square kilometer than China.)

Comparing the renewable share of electricity consumption is probably more relevant and more telling (see also Figure 1.7): worldwide, wind and solar account for 3.6 percent. This can be contrasted with Denmark, which in 2014 derived 39.1 percent of its electricity demand from wind

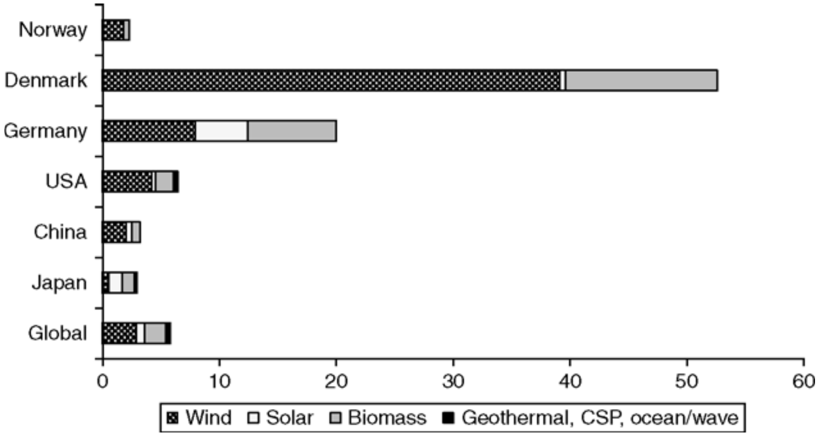

Figure 1.7 Non-hydro renewable share of electricity consumption, 2012–14 (percent)

Note: CSP = Concentrated Solar Power.

Sources: Figures and projections based on *BMWi* (2014c); DEA (2013); EIA (2014a, 2014b); *Energinet.dk* (2015); *ISEP* (2014); *METI* (2014b); NEA (2013); REN21 (2014); *SINTEF* (2012).

power alone, and where in December 2013, for the first time in any major country, wind power provided more than half the electricity for an entire month (54.8 percent).[13] Germany comes in at 20 percent. However, wind and solar only account for 12.5 percent, with almost 8 percent from wind and 4.5 from solar (the rest is biopower).[14] Still, with Denmark, Germany belongs to a group of EU countries that derive significant portions of their electricity from renewable energy. Spain, for instance, derives 21 percent from wind and Italy almost 8 percent from PV, and the EU as a whole roughly 20 percent from renewables altogether (including hydro). In contrast, Japan, China, and the US only get 3–5 percent from non-hydro renewable energy. In the US, 4 percent comes from wind, a quarter of a percent from solar and 2 percent from biopower and geothermal. In Japan, despite the late surge in solar installations, less than 2 percent is provided by solar and about half a percent from wind, with non-hydro renewables in total accounting for 3–4 percent, whereas in China, the total figure is somewhere around 2.8 percent, of which 2 percent from wind and 0.7 percent biomass. This comparison may also not be entirely fair, considering that China is a developing country, not yet having made the same major strides in energy efficiency as the others. It does, however, reveal fairly major differences between the countries. Norway is still the most different. Less than 2 percent is derived from wind power, but with hydropower accounting for 96–98 percent of all electricity, Norway is in a league completely of its own if hydropower is included in our comparisons (*BMWi*, 2014c; DEA, 2013; *EIA*, 2014a; *Energilink*, 2013; *Energinet.dk*, 2014, 2015; *ISEP*, 2014; *METI*, 2014b; NEA et al., 2014; REN21, 2014; *Vindportalen*, 2015).

If we look at investments in 'renewable power and fuels', the picture is a bit checkered as of late. The overall trend is one of massive growth, from less than $40 billion in 2004 to more than $200 billion today. But the financial crisis has led to renewable investments taking a few hits. 2009 was a lean year, but was saved by growth in Chinese investments. Beyond that, investments peaked in 2011 at $279 billion and, including large hydro, net renewable power capacity investments that year was actually $40 billion higher than net investments in fossil fuel capacity. However, since then, the road has been rockier. Investments fell by 10 percent in 2012 and another 17 percent in 2013, dropping to their lowest level since 2009 (although tentative figures suggest a bit of a rebound in 2014).[15] Some of these figures are less serious than they look, since both PV and wind power equipment has become dramatically cheaper over the past couple of years (REN21, 2012, 2014).[16] Thus, it now takes lower investment levels to install the same capacity as only a few years ago. And the general sentiment is that despite this bump in fortunes, investments should start rising again. Clean Edge (2014b), for instance, projects nearly $400 billion worth of investments by 2023.

However, these are aggregate figures, and breaking them down by country and region makes it evident that growth has become bumpier. Europe is, for instance, sharply down, the US somewhat down, and China more or less steady (see Figure 1.8). It also offers an insight into what is currently one of the biggest problems in the industry, namely boom-and-bust cycles. Booms in US investments have, for instance, had much to do with rushing to take advantage of federal support policies that are about to come to an end. And the aggregate figures hide the fact that in 2013, the US saw both a simultaneous boom in PV installations and a bust in wind power, when from the previous year installations dropped from 13GW to 1GW (GWEC, 2012, p.12; REN21, 2012, p.47). German investments peaked in 2010 at $33.7 billion, but have since then dropped for three years in a row, down to only a little more than $10 billion in 2013, and European investments in general have dropped by almost 60 percent since 2011. In 2011, Italy and Germany alone accounted for 57 percent of the new PV capacity worldwide. But the

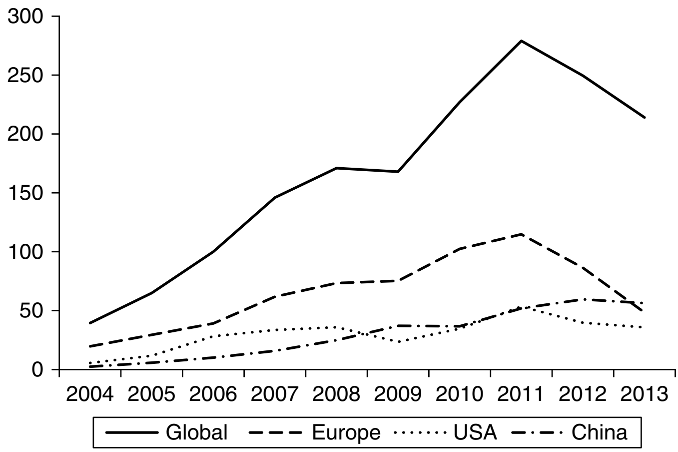

Figure 1.8 Global new investment in renewable power and fuels, 2004–13 ($ billion)

Note: Figures include biomass, geothermal and wind generation projects bigger than 1MW, all hydro projects between 1 and 50MW, all solar projects, all ocean energy projects, and all biofuel projects above one million liters of annual production capacity (REN21, 2014, p.15).

Source: REN21 (2014).

boom year of 2011 was followed by bust, as European countries experienced setbacks from setting feed-in-tariffs (FITs) too high. Italy installed more than 9GW in 2011, but only 1.5GW two years later, as the Italian and the other European markets imploded. Spain has discontinued its FIT altogether, deeming it too expensive. Germany in 2014 paid an estimated €24 billion in subsidies for all forms of renewable energy, and has now passed an energy reform which may phase the FIT out altogether by 2017 (Asano, 2012; *BMWi*, 2014a; *Reuters*, 2014b). For quite a few years, huge sums of money were spent on subsidies in what is still a financially stricken continent, and while it has often been argued that the installation of renewables is good in terms of both energy supply and in creating jobs, European countries in the midst of a heavy financial crisis have experienced not only that FITs are expensive, draining the rest of the economy of money that might have been better spent elsewhere (e.g. Marques and Fuinhas, 2012) – at least in terms of jobs and deficits – but also that the main result is an influx of cheap Chinese imports rather than job creation and export industries at home. In 2013, not even Chinese investments continued to rise, even if they are by now by far the world's highest, whereas the number one bright spot was Japan, where renewable investments increased from $9 billion in 2011 to nearly $29 billion in 2013. This is a consequence of the changes brought on by Fukushima. Whether or not the generous FIT introduced in 2011 can however be maintained is an open question. Asano (2012) criticizes it for being both costly and primarily leading to imports from China, and that Japan may end up with the same kind of boom and bust as seen in Europe.

If we break the investments down to wind vs. solar, we see the same trend. Solar investments have increased dramatically. In Germany PV has taken 76 percent of the renewable investments since 2008, and in Japan more than 90 percent. Globally, since 2010, solar PV has attracted more investments than wind power (see Figure 1.9). Still, in 2013, solar PV investments reached their lowest level for three years, primarily because of the European (in particular, the Italian and German) solar boom and bust (PEW, 2014; REN21, 2014). Wind power relies on more mature technologies and has seen less of a drop in costs over the past few years. Thus, it has been less volatile than solar.

That wind is a more robust sector than solar can also be quite clearly seen if we look at the wind turbine and solar PV *industries*. In both industries costs have fallen greatly. Wind turbines prices have fallen by 30–40 percent since 2008, whereas solar PV module prices have dropped by a full 80 percent (before stabilizing and increasing slightly in 2013–14). For wind power, technological progress has been key to explaining the

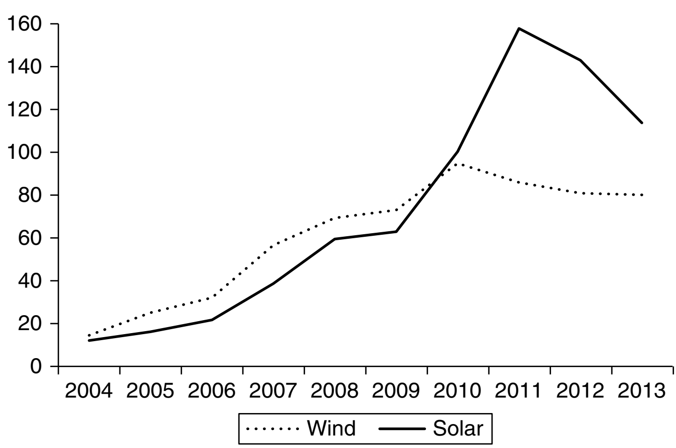

Figure 1.9 Global new investment in wind and solar power, 2004–13 ($ billion)
Source: REN21 (2014).

decrease in costs (although raw material prices are also important). For PV the story is a bit different. Here, essentially PV technologies have become turn-key. The technologies are now fairly commonplace, with energy conversion efficiencies nearing their technological limits. Thus, PV manufacturers are competing on costs rather than on technological sophistication. This may be in the process of changing – REN21 (2014) reports that innovation and product differentiation is again becoming important – but the astonishing cost reductions have come more as a result of oversupply than technological improvements (AWEA, 2014; Caldecott, 2013).

This oversupply stems primarily from China, which very much dominates the global market with a market share of roughly 60 percent. China now also has the largest domestic PV market, but domestic growth is a very recent phenomenon. Until recently, China was a minor player in terms of installations while feeding off generous FITs in other countries, primarily in Europe. Japan used to be the dominant player – it had more than 50 percent of the market share in 2004, and Sharp was the world's largest PV manufacturer – but since 2005, the decline in fortunes has been rapid. China now has 9 of the top 15 PV manufacturers in the world. Market leaders have come and gone. As of 2013, China's Yingli Green Energy and Trina Solar have the largest markets shares (both in crystalline module production and in PV modules). Other big companies include the US First Solar, Canada's Canadian Solar, and Sharp and Kyocera of Japan, but the rest are Chinese. While the rank order of these companies changes around somewhat from year to year, the striking fact is the overwhelming Chinese dominance (*GlobalData*, 2014; REN21, 2013a, 2014).

The Chinese market glut means that Chinese manufacturers are also struggling. But with profit margins all over the world becoming wafer-thin, this favors manufacturers in low-cost countries, such as China, rather than Japan, Europe, or the US. Ernst and Young (2012b) in 2012 predicted that by 2015, 180 solar module companies would go bankrupt (including more than 50 Chinese). A number of once very prominent German firms, such as Solarhybrid, Solon, Solar Milennium, and Q-Cells have already disappeared, whereas Norwegian company REC – a top 15 company as late as 2012 –closed down its Norwegian operations in 2012. The industry has enough capacity for 60GW of installations (China alone at one stage had a capacity equal to almost 200 percent of the world market), but even in the record year of 2013 installations did not go beyond 39GW, with an estimated 45–49GW in 2014, and it is unlikely to go beyond 60GW quite yet (one estimate suggests 56GW for 2015), even when factoring in major growth in China and Japan (*Economist*, 2012a, 2013a, 2013b; *pv magazine*, 2014a; reneweconomy, 2014b; *TU*, 2012b; *SolarServer*, 2015).

Generous FITs in wealthy countries have to a major extent spurred Chinese imports rather than domestic job creation. This is also the reason why solar FITs have been cut in many parts of the world, making the Chinese PV industry far more dependent on having a home market. The bankruptcy of Chinese giant and former market leader Suntech Power shows that even the Chinese are not immune to the glut that they essentially themselves created. Reports speculate that some Chinese manufacturers were losing $1 for every $3 of sales in 2012 (*New York Times*, 2013). China's top-ten PV companies have total debts of $16 billion (REN21, 2014). This can hardly continue. Thus, consolidation needs to happen within China as everywhere else. But this may not come easily, and Suntech itself is proof of that. After its bankruptcy it was immediately bailed out by the local government, which feared for both the social and financial consequences of the company having to close down (see otherwise the China chapter (Chapter 3)). The central government knows that the industry desperately needs to consolidate, but other companies have also been bailed out by local governments. In addition to this, accusations of dumping, against China, from both Europe and the US is creating extra turbulence within the industry.[17]

Consolidation has also been the case in wind turbine manufacturing, but there is already far more concentration in wind turbines than in PV. Whereas in PV the ten largest manufacturers control no more than 40 percent of the market, the ten largest wind turbine manufacturers control more than 70 percent. Another major difference is that in wind, the Chinese, despite having by far the largest home market, and despite accounting for 30 percent of installations worldwide in 2012 and a massive 45 in 2013, are less dominant. Danish frontrunner Vestas has had the largest (although dwindling) market share every year since 1999 (barring 2012). Other major players are Germany's Enercon and Siemens Wind and US' GE Wind. Chinese company Goldwind was second largest in 2013, and other major Chinese manufacturers are Sinovel and Mingyang. However, the Chinese manufacturers rely almost entirely on their home market, and do not export to any great extent, more or less exactly the opposite of the situation in PV.[18]

Developments are rapid. Not long ago 2MW represented the pinnacle of wind power development. As of 2013, the *average* wind turbine size is 1.9MW, whereas the largest commercially available turbines produce

7.6MW. Offshore, 5–8MW turbines are being tested. Onshore, wind-generated power is now often cost-competitive on a per kWh basis with coal- and gas-fired plants, even without subsidies (REN21, 2014).

In the PV sector the main problems have been oversupply and a strong need for consolidation. They are still major problems, but the industry seems to be headed in the right direction. For wind power, the grid net is one of the biggest problems. With the rapid expansion of wind power, evermore countries are having problems feeding ever larger amounts of renewable electricity into the net. Problems range from a lack of infrastructure to delays in grid connections to curtailment of electricity generation. In several countries, the expansion of renewable energy has run ahead of the expansion of the grid system. Thus, lots of primarily wind, but also solar, power has been lost because the grid has not had the capacity to absorb it, and approximate estimates suggest that the European grid infrastructure requires €1 trillion worth of upgrades before 2020, whereas the US infrastructure requires more than $2 trillion by 2035 (*Economist*, 2013e; GWEC, 2014; *Power*, 2014e, 2014f; REN21, 2014).

The holy grail of renewable energy, or at least so it seems, is still grid parity, and so a few words need to be said about this as well. In other words, to what extent is renewable energy actually competitive without subsidies? As always, the answer is complicated and full of contingencies. Grid parity is the point at which an alternative energy source is able to generate electricity for the same levelized cost[19] as the electricity that is available on a utility's transmission and distribution grid. Hence, once grid parity is reached, it should be possible for renewable energy to keep growing even without government support. Grid parity is, however, no neat and easy concept, and implies no fixed value. Instead, electricity rates vary considerably in different locations, and thus grid parity will be more easily achieved in countries with more expensive electricity (the US, for instance, has cheaper electricity than most European countries). There are also differences in how well suited different locations are to wind and solar. Germany – with the world's highest installed PV capacity – receives far less sun than most of the US, and so solar power is less effective in Germany, irrespective of the actual capacity installed, and grid parity will take longer to achieve than, for instance, in California. There is also the difference between retail and wholesale prices. Retail prices (the price paid by consumers) are usually far higher than wholesale prices. This applies in particular to PV, where individual customers are facing retail prices when they decide whether or not to install a solar rooftop panel, whereas for a utility, the wholesale price is what determines whether or not it is profitable to invest (*REA*, 2014; *RenewableEnergyWorld.com*, 2014b).

This means that the answer to whether or not grid parity has been achieved, or when it will be achieved, is: 'it depends'! Granted, we can be slightly more precise. PV is, for instance, competitive with retail (not wholesale) prices in Germany, Italy, and Spain, as well as in ten US states. Deutsche Bank predicts a second takeoff in solar installations based on their estimate that 19 countries will reach retail grid parity for solar in 2014. In wind power, grid parity was reached in some locations as early as 2010. This, however, varies, as some countries have much longer transmission distances than others, with for instance the US expected to reach grid parity for wind no sooner than 2016. However, the general consensus, irrespective of local conditions, is that grid parity is indeed not extremely far off. There is, however, one or two more problems. If lots of wind (or solar) power is added in areas that are already abundant in wind (or solar) power, days that are calm (or cloudy) will yield major intermittency problems. Thus, unless the transmission net is good enough that power can be easily transmitted from areas with wind (or sun) to areas without, then significant standby capacity is needed as a backup. Thus, for renewable energy to compete, it needs to be both competitive on price *and* able to predictably produce power, all day and all year, irrespective of backup loads from coal, nuclear, or hydro. Thus, even if renewable energy has reached grid parity, intermittency and grid problems may lead to utilities still considering fossil fuels and nuclear as their staple energy. There is an obvious mismatch between the electricity that renewables provide and what the utilities are able to feed into the grid, and this has to be solved for any energy transformation to take place (*Climateprogress*, 2014; *Energías Renovables*, 2012; *pv magazine*, 2014a; *REA*, 2014).

This mismatch, however, also provides a potential source of disruptive change, namely in the growth of what IEA-RETD (2014) calls *prosumers*, that is, energy consumers who produce their own power. PV is the most disruptive of the energy technologies, since it allows consumers to produce their own power. Germany, for instance, has a full 1.4 million PV producers. Thus, where the utilities represent a top-down approach, with large infrastructures, large cross-continental transmission lines, large electricity storage systems, and long planning times, with renewable energy only uneasily included, PV represents a bottom-up, decentralized challenge, where electricity is instead produced locally, by the individual consumer. In countries where retail grid parity has been achieved (as in Germany), it makes good sense for consumers (or prosumers) to produce their own power rather than purchasing it from the utilities, and in doing so driving the growth of a completely different, and rapidly expanding, model of electricity generation (IEA-RETD, 2014; Schleicher-Tappeser, 2012). The IEA-RETD (2014) stresses that we are not yet at a point where a prosumer 'revolution' has occurred, but that prosumers represent the greatest challenge so far for the utility companies that have dominated the electricity markets for the past century, as well as providing major potential for creative destruction in, and a transformation of, the entire utility sector.

The structure of the book

In the following chapters, I will look at the renewable energy policies of six different countries – Japan, China, the US, Germany, Denmark, and Norway. The chapters all include a mixture of comparative and case-study methods. Why these six? These are very different countries. There is obviously a wealth of countries that could have been interesting for the purpose of such a book, and so implicit in every choice of one country, is the omission of another. Yet, in China, Japan, the US, and Germany, we have four of the most powerful and influential economic and industrial powers on the planet, and the policies that they implement will be of huge significance to the rest of the world. Denmark and Norway are two countries that are both too small to serve as movers and shakers of the world economy, yet still highly interesting. Denmark is in many ways the original leader in (modern) wind power and, while its leadership is challenged today by China, the US, and Germany, it very much remains among the leaders. Norway is a completely different story, and in many ways a counterpoint to all the others. With its huge petroleum resources and its hydropower, the Norwegian discourse on energy and renewables has often looked distinctly different from that of other countries. Thus, there is a lot of variation in the policies, the energy structures, the vested interest structures, and even the development level of these countries. This is fertile ground for comparison.

They are all analyzed and compared according to a fairly loose theoretical framework that focuses on the influence of vested interests on energy-political decision-making. Each and every country chapter can be read as complete, stand-alone chapters, independently of the others. However, the vested interest focus provides a unity of perspective. The intention is that while each chapter is a finished whole, they should be structurally so similar that it becomes easy to make comparisons between them. Thus, every chapter starts with an introduction that sketches out the general story, followed by a section on the status and progress of the development of wind and solar power in that country. Then follows a section with a more explicit political economy focus, namely on vested interests and the extent to which renewable energy policy has been constrained by the vested interest structure, before I draw my conclusions in the final section of the chapters. In addition, countries often have country-specific features that do not fit into the overall structure. Thus, several chapters have sections that are specific to that individual country. But, obviously the reason why the chapters are more or less similarly structured is to ease comparison. In other words, the purpose of the book, beyond providing empirical knowledge of the renewable energy policies of six different countries, is to say something more general and systematic about what drives renewable energy policy and the expansion of renewables. Thus, one of the general conclusions springing out of this book is that success within renewables depends crucially on being able to control the influence of its vested interests. That vested interest structures are a major influence in all of these quite different countries goes a long way toward substantiating their importance in the political economy of present-day energy policy, and also substantiating that very often the political constraints against renewable expansion are the ones that need our attention. And that no energy transformation will take place if we lose sight of that.