

CHAPTER I

Introduction – what are the drivers of decentralised renewable energy generation?

The entire world is moving towards decentralised energy generation. A couple of years ago, this statement would have been the vision of a distant future. No one would have believed that within less than a decade the existing configuration of power supply would be fundamentally challenged. In large parts of the world, decentralised energy generation means *renewable* energy generation, because solar photovoltaic panels and wind turbines are scattered across residential rooftops and dispersed on acres and farmland. They constitute a fundamental reversal of the paradigm of economies of scale that used to dominate the economics of the energy supply industry in the 20th century.

Of course, the old system of large thermal and nuclear power plants, centralised dispatch, and long-distance transmission lines will co-exist for several decades to come. It brought nation states a reliable supply structure, even though future generations may have to bear the welfare losses for its legacy with respect to climate change, nuclear waste, and stranded assets.

Curbing greenhouse gas emissions has become a global imperative to prevent a lasting, negative impact on the development path of future generations. One of the least contested policy options is a carbon-neutral energy supply. Regulators and politicians have significantly contributed to the rise of renewable generation that promotes a shift towards a sustainable supply structure. In many industrialised countries, they opted for generous subsidy schemes that helped manufacturers of renewable generation technologies, in particular solar and wind, to scale their operations and drive costs down. Now politicians have to find solutions about how to maintain a resilient system in spite of a substantial share of intermittent, weather-dependent, and decentralised renewable supply.

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Many emerging economies, most notably China, whose domestic energy policy is discussed in Section 2.3 of this book, but also highly industrialised states such as California, which we explore in Section 2.8, experienced government regulation that has led to a *centralised* dissemination of renewable energies, with large-scale, utility-owned installations of photovoltaic fields and wind parks. Often, this is a fast and efficient way of reducing the carbon footprint of energy supply. However, we believe that the true revolutionary potential of these recent changes of the supply structure relates to the empowerment of the final consumer to transcend into a local, sometimes even autonomous producer of energy, as it occurred in countries such as Australia, Germany, or Denmark.

Most importantly, in developing countries decentralised renewable generation may lead to leapfrogging of certain stages of infrastructure development, analogous to the usage of cell phones instead of building a fixed network for landline telephony services. Especially in rural areas, it may provide a complementary service to the existing energy infrastructure, with individual households establishing micro-grids that enhance commercial activities and, literally, improve the quality of life of local residents.

In industrialised countries, the looming age of decentralised generation does not mean that all utilities will disappear within the next decade. But those utilities that are unable to adapt to the new market environment may one day be swallowed by players from the information and communication technologies or manufacturing sectors, or shrink in their position from providers of a critical infrastructure service to the equivalent of a telephony retailer or private insurance company. A whole range of new players will enter energy markets and redefine business models, revenue streams, and risk allocation. Information and communication providers as well as start-ups occupy commercial niches in decentralised energy generation that utilities are not capable or willing to enter; they provide financing options, technical advice, operation and maintenance of assets, and care for their customers' needs.

Most importantly, though, this movement is not only a global transformation, it is an individual transformation too: across the globe, private consumers decide to turn into micro-investors for their personal generation and, increasingly, storage devices. Collectively they contribute to the renewal and reconfiguration of the energy system.

In the remainder of this first chapter, we want to highlight six key trends that characterise and shape the momentum of change within the energy sector, namely the competitiveness of renewables and decentralised generation (Sections 1.1 and 1.2), the rising role of storage (Section 1.3), the decoupling of growth and energy intensity (Section 1.4), enhancing local value creation (Section 1.5), and digitalisation as enabler of smart grids and new business models (Section 1.6). We will focus on electricity as the segment of the energy sector that is most fundamentally transformed. An analysis of other changes, in particular the role of efficiency and the electrification of transport, would generate equally relevant insights, but is unfortunately beyond the scope of this research.

The introduction will then serve as the basis for the discussion on diverging regulatory models of the electricity supply industry, which will be discussed in Chapter 2, and the emergence of new business models in the context of developing and industrialised countries in Chapter 3. We will conclude the book with a chapter on concrete policy recommendations and the main attributes of successful business models in Chapter 4, which describes the three stages of current, decentralised energy supply, and Chapter 5 as an executive summary of the major findings of both top-down and bottom-up approaches to promoting renewable energies on a global scale.

With this endeavour, our desire is to encourage political and corporate decision makers to assess the most appropriate model to support a future electricity system, adapted to local market conditions, encouraging entrepreneurial activity that minimises the carbon footprint, while ensuring that the conflicting energy triangle of security of supply, resource efficiency, and sustainability is secured for the generations to come.

1.1 Renewables becoming competitive

We may perceive the recent rise of consumer empowerment as a more fundamental disruption than previous changes. Energy policy has undergone major shifts in priorities since the beginning of the 20th century, and each change was perceived as a radical break with the status quo.

Prior to the 1970s, energy policy was primarily focused on affordability; increasing the proportion of the population which had access to energy networks and adding capacity to match economic development. The oil crises of the 1970s led to new directions for energy policy in many parts of the world, including Europe, the US, and Japan. These new energy policies can be broadly divided between those countries or states which tried to improve energy security through reducing oil use by developing other sources of primary energy supply, particularly for electricity, and by using energy more efficiently (for example, California, Denmark, and Japan); and those countries which by and large continued to be dependent on oil – either by developing their own oil resources or attempting to diversify their supply.

Energy policies around the world continued to be dominated by security concerns until environmental matters – including acid rain, the ozone layer, climate change, and local air pollution – began to gain importance in the 1980s and 1990s. In December 1997, the Kyoto Protocol was the first global effort to curb greenhouse gas emissions. Simultaneously, the liberalisation and privatisation of many public infrastructure services also affected regulation in the energy sector. With a focus on increasing efficiency via market mechanisms, liberalisation paved the way to implement competition in the generation and retail segments of the electricity supply industry.

The combination of emission reduction targets with a competitive, market-oriented regulation of the electricity sector has led to an unprecedented rise

of renewable energies. This both reduces the dependency on fossil fuels and accelerates the deployment of decentralised, climate-friendly energy sources. If humankind wants to curb carbon dioxide emissions to ensure that global temperature rises remain well below 2°C and strive towards a rise of ‘only’ 1.5°C, as stated in the Paris Agreement in 2015 and ratified by almost 180 countries, as of August 2018, decentralisation is increasingly seen as a ‘no regrets’ strategy for meeting the core energy policy goals.

For governments, there is no single trajectory, no ‘one size fits all’ strategy. A few countries choose nuclear as an (almost) carbon-neutral power generation technology, while in most other countries the nuclear power fleet faces decommissioning within the next decade or two. Cost overruns and severe delays in the majority of new nuclear plant constructions in Europe (Schneider & Froggatt 2019) makes it seem unlikely that the technology will experience a renaissance in the Western world. Similarly, carbon capture and storage (CCS) as a means to reduce greenhouse gas emissions faces severe opposition from local residents, and many pilot projects in the Western world have been prematurely ceased. As these two options do not seem to be politically desired and economically feasible in multiple jurisdictions, it is renewable energy that is the most likely substitute for fossil fuels.

The price of renewable electricity technologies, such as onshore and offshore wind and solar photovoltaics, has fallen rapidly in the last decade. This is because of lower prices due to increased competition, a shift in production to lower-wage economies (from Europe to Asia), technology improvements, and economies of scale. In Europe, the cost of solar modules decreased by 83 per cent between 2010 and 2017. According to an International Renewable Energy Agency (IRENA) estimate, the global weighted average LCOE of utility-scale PV plants has fallen by 74 percent between 2010 and 2018, from US\$3,300–7,900 per kW range in 2010 to US\$800–2,700 per kW in 2018. The utility scale solar PV projects commissioned in 2018 had a global weighted-average LCOE of US\$0.085 per kWh, which was around 13 percent lower than the equivalent figure for 2017 (IRENA 2019).

While even for the more mature wind turbine industry, costs have fallen. For wind in 2018, new capacity was commissioned at a global weighted average LCOE of US\$0.056 per kWh, which was 13 percent lower than the value for 2017 and 35% lower than in 2010, when it was USD 0.085 per kWh (IRENA 2019). These falling technology costs and ongoing policy support have led to renewables now dominating new build in the power sector. In the global electricity supply, an additional 181 GW of new renewables capacity was installed in 2018, the largest ever annual increase, 65% of all new supply investment (Ren21 2018). Going forward the trend is expected to continue with solar and wind, according to Bloomberg New Energy Finance, to attract 73 per cent of investment in the power sector between 2017 and 2040 (Henbest 2017). As a consequence, onshore wind and solar PV power are now, frequently, less expensive than any fossil-fuel option, without financial assistance.

Table 1: Examples of Cost of Solar and Wind Projects 2017–9.

Country	Price-US\$/MWh		Details
2017			
India	37	Solar	Indian developer ACME Solar emerged as the winning bidder for a 200 MW project with a tender price of ₹2.44 per kWh.
Germany	63	Wind	The introduction of auctioning for wind for the first time for onshore wind installations led to an average bid of 5.71 cents per kWh for 70 bids with a total installed capacity of 700 MW – 93% of the bids (65) or 96% of the volume of bids were awarded to citizens' energy companies.
Chile	32.5	Solar/ Wind	An average price of \$US32.5 per MWh was awarded for 600MW of solar and wind capacity.
India	38	Wind	A wind energy auction for 500 MW of capacity and organized by the state government of Gujarat revealed a tariff of Rs 2.43 per kWh as the lowest bid.
2018			
Germany	55	Onshore wind	In total 83 bids were awarded for a total of over 700MW of capacity. The range of successful bidders was €38 per MWh to €52.80 per MWh with an average of €47.3 per MWh.
United States	36	Onshore wind	The levelized cost of wind also hit an all-time low, averaging \$36 per MWh for plants built in 2018 across the United States.
Brazil	21	Wind	In April 114MW of wind was contracted in a tender at a price of R\$67.6 per MWh for capacity contracted from four projects in the north-eastern state of Bahia.
India	35	Solar	In July 2018, ACME Solar quoted the lowest tariff of ₹2.44 per kWh for 600 MW of solar projects in the Solar Energy Corporation of India (SECI)'s 2 GW ISTS Phase I auction.
2019			
Saudi Arabia	17	Solar	Saudi Arabia's Acwa Power submitted a tariff of just US\$c 1.6953 per kW for the 900MW fifth phase of Dubai's Mohammed bin Rashid Al Maktoum (MBR) Solar Park

Table 1: Continued.

Country	Price-US\$/MWh		Details
US	19.9	Solar	In June a 400MW project in Los Angeles was agreed at US\$c1.997 per kWh.
Portugal	16.6	Solar	In July, the Direcção-Geral de Energia e Geologia awarded a series of contracts to provide 1.15GW of solar energy. Within that, 150MW was secured for a price of just €0.01476 per kWh.
Saudi Arabia	20	Wind	In August it was announced that the costs of electricity from the 400MW Dumat Al Jandal onshore wind farm would be US\$c 1.99 per kWh.
UK	50.0	Offshore wind	12 projects, including 5.5 GW of offshore wind projects, at record low prices as low as £39.65 were contracted.

A broader experience in the siting of renewables, faster installations, and lower related costs, as well as an increase in conversion efficiencies have contributed to further reduce the cost of energy produced from renewables. Significant improvements have been achieved because of a move to renewable auctions, although there are critical voices as to the long-term viability of these cost reductions and their impact on the diversity of market actors. (Klessmann & Tiedemann 2017). Nonetheless, these have resulted in a decrease in the price per megawatt and contracts for large-scale renewable technologies, as can be seen in Table 1.

Although globally renewables are still a relatively small share of total power production, around 5 per cent, in selected countries and regions they have become significant providers of electricity. In 2018, wind energy provided an estimated 11.8 per cent of EU annual electricity consumption – including Denmark, which met 41 per cent of its annual electricity consumption with renewables. Globally, at least 12 countries, including Costa Rica, Nicaragua, and Uruguay, met 10 per cent of their demand from wind. In 2018, solar PV accounted for 12.1 per cent of total generation in Honduras. Significant shares can also be observed in Italy and Greece (both about 8.2 per cent), and by late 2018 one in five Australian households generated at least some of their electricity with solar energy (Ren21 2019).

Bloomberg New Energy Finance (BNEF) has published its analysis for investment in global clean energy which shows that 2017 was the second highest ever, with US\$333.5 billion, despite falling technology costs (Louw 2018). Globally, the solar sector in China dominated, with a total of US\$132.6 billion of investments – leading to over 50 GW of additional solar capacity. As the figure 1

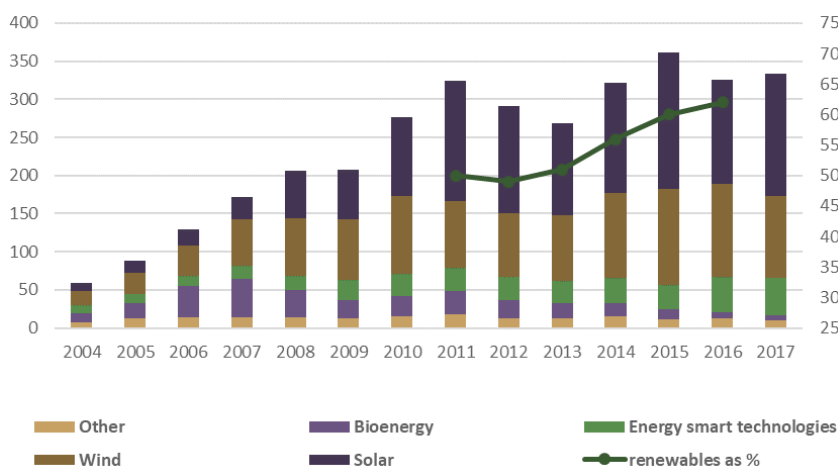


Figure 1: Global investment in clean energy by sector (US\$ billion).

Source: BNEF (2018), UNEP 2010–2017 Status Reports.

shows, growth in solar investment has continued at pace over the last decade. The graphic also indicates the extent to which the deployment of renewable energy, including hydropower, has come to dominate total new capacity in the power sector, moving from around 50 per cent at the turn of the century to, in 2016, comprising of 62 per cent.

In regional terms Asia, largely China, dominates the global landscape, with Europe, once the world leader, continuing to decrease the level of investments. In 2017, European investment totalled US\$57.4 billion, down from US\$137.8 billion in 2011. In the United States, investment in clean energy grew marginally to US\$56.9 billion in 2017, with a peak in 2011, similar to Europe, in the United States at US\$62.3 billion. Mexico and Australia saw 2017 investment levels at an all-time high of US\$6.2 billion and US\$9 billion, respectively.

In terms of installed capacity and output, the European Union still is a global leader in renewable energy. In 2017 across the bloc, renewables, including hydropower (9 per cent), renewables provided 33 per cent of electricity, more than any other source (Sandbag 2019).

While renewable energy deployment has been initiated by national policies and measures, with 179 countries having renewable energy targets on the national or state or provincial level (Ren21 2019), this is expected to accelerate, as equipment and production costs for small-scale renewables continue to fall and reach grid parity¹ in many regions of the world. However, this is only the first step. The next step is when renewables are able to achieve ‘energy system

¹ Grid parity (or socket parity) occurs when an alternative energy source can generate power at a levelised cost of electricity (LCOE) that is less than or equal to the price of purchasing power from the electricity grid.

parity', which would include the system integration costs (the costs of balancing and reserves). Energy system parity is likely to be achieved once integrated, smart energy systems or decentral storage solutions come into place.

1.2 The global spread of decentralised energy generation

From a global perspective, energy technologies, energy system operation, and energy ownership are also decentralising,² with investment in distributed energy continuing to grow, especially for solar PV, as is shown in Figure 2. In 2017, both large-scale and small-scale solar picked up again close to 2015 figures.

As the country reports in Chapter 2 demonstrate, there are some countries in which decentralised energy is playing an increasingly important role in the supply structure.

In 2017 the worldwide investment in solar projects of less than 1 MW was US\$49.4 billion, installing 29 GW. China rapidly increased its investment five-fold in 2017, totalling US\$19.6 billion of investment in small-scale projects, almost 40% of the global total. While the global investment in small-scale renewables is much less than the peak in 2011, of US\$76.2 billion, as the cost of solar has fallen 57% over the same period, the annual installed capacity is the largest yet (Frankfurt School-UNEP 2018).

For a couple of years, Japan dominated the country ranking of investments in decentralised renewable energies, with a total of US\$31.7 billion in 2015. The rise of renewable deployment in Japan was, in part, a response to the accident at the Fukushima nuclear power plant in 2011 and the subsequent temporary closure of all nuclear power plants. Since then, much to the discomfort of the national government, restart of the reactors has been extremely slow. At the end of the year 2018 only nine plants were in operation, down from 54 prior to the accident.

Australia has seen rapid growth in the deployment of solar, especially on the household level. Despite cuts in government support, deployment of PV has continued, because its decreasing costs turn them into economically attractive alternatives to paying the retail price of electricity. By the end of 2017,

² By decentralising we mean: technologies themselves are in smaller capacity units, and their geographic distribution is wider. The system is moving from a one-way, top-down, supply-orientated operation of a few, large conventional fossil power plants to a system operation in a bi-directional way, demand focused, with multiple, varied power generating units of all sizes. Whereas ownership used to be state-owned monopolies, or large utilities, increasingly there are new entrants with non-traditional business models which provide particular services, for example suppliers that only sell renewable energy; former municipal utilities that diversify their services; independent platform providers which establish local energy markets; intermediaries who manage demand-side response.

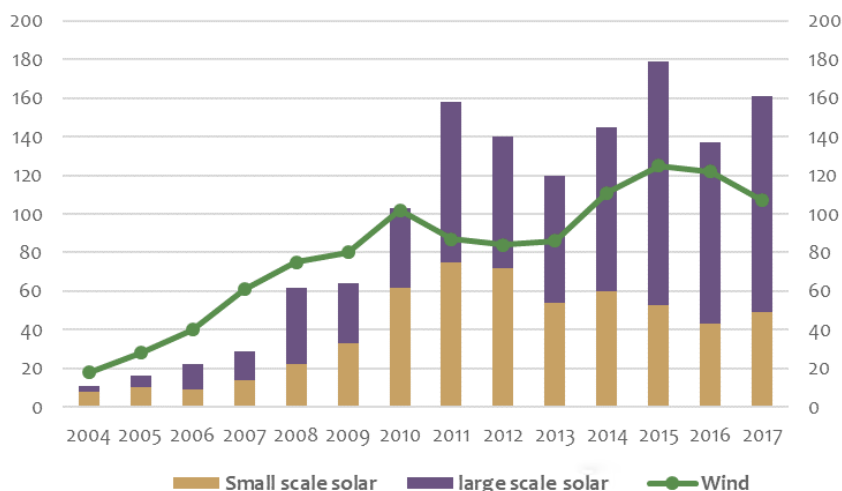


Figure 2: The global deployment of solar and wind power (GW).

Source: BNEF 2018.

cumulative installed capacity for solar PV systems in Australia stood at 6401 MW with close to 1.8 million installations, an increase from 5463 MW and 1.64 million installations the previous year (AEC 2018). By the start of 2018, over 30 per cent of homes in Queensland and South Australia had solar panels (Australian PV Institute 2018).

Across Europe around two thirds of solar systems are located on the rooftops, be they residential, commercial, or industrial. In Germany, there are approximately 1.5 million solar PV systems (GTAI 2018) with a total installed capacity of nearly 43 GW by the end of 2017, but only a small amount of utility-scale solar units. By contrast, utility-scale solar accounts for 20 per cent of the approximately 20 GW PV capacity within the Italian system – there are still over 700,000 separate solar installations (Gianni 2017).

In the United States in 2017, around 28.5 GW of electricity generating infrastructure was deployed – 25 GW utility scale and about 3.5 GW of distributed (that is, smaller than 1 MW) solar power – of the total, wind and solar were 55.4 per cent. However, when looking at net additions with the closure of 11.8 GW of utility-scale fossil fuel plant retirements, the net new volume of US generation was 16.7 GW of generating capacity, with 94.7 per cent of that coming from renewables (Weaver 2018). In comparison, India's rooftop solar accounts for 9 per cent of the country's solar capacity. In Japan, around 11.8 per cent of new solar additions are on rooftops (REN21 2018).

China has experienced a massive increase in deployment of decentralised renewable technologies. Over the last few years, China has shown that without the engagement of customers and the public, renewable energy, in particular

solar and wind, can be deployed at scale too. These deployment rates, 53 GW in 2017 alone, have had a profound impact on global technological manufacturing costs. There has also been a shift towards distributed capacity, with about 19.4 GW of capacity added in 2017, up from 4.2 GW in 2016, including a three-fold increase in rooftop solar to 2 GW (REN21 2018).

The rapid increase in the deployment of renewables has most often been driven by specific targets or policy interventions. In the case of Germany and Italy, the availability of feed-in-tariffs (FiTs) led a boom in PV deployment, including significant small-scale and individually or community owned. In some countries, the effect of price guarantees was underestimated. Programs were exploited in a short time leading to high overall costs for the support schemes and started to affect other market actors, traditional generating companies, and the grid operators. Consequently, fiscal support schemes – reductions in the FiTs and more recently changes in rules about grid access – have slowed down, and in some cases completely stopped.

By contrast, the developing world is leapfrogging into a decentralised energy supply infrastructure. In developing countries, micro-grids and solar-storage kits for individual households co-exist at the periphery of the central grid and may in future substitute the rollout of the public transmission network, comparable to the phenomenon of leapfrogging from no telephone service to hand-held devices without passing the stage of line-based telephony.

1.3 Decentralised storage gaining importance

The greater deployment of renewables, particularly those with weather-dependent, variable production, is increasing the need for grid flexibility and reducing the need for traditional base-load generators. A key technology to increase flexibility is storage technology. An assessment by the US Department of Energy suggests that storage will increase the possibility of economic deployment of variable renewables from 16 per cent to 55 per cent (NREL 2016).

Storage technologies will also enable the greater use of electricity in other sectors, such as heat and transport. Recognising these cross-sector benefits has resulted in increased efforts in research and development, leading to greater deployment and creating a virtuous circle of falling, higher technical potentials, and further deployment.

Advances in storage technologies are especially important for electric vehicles, as they face the trade-off between weight of the batteries and restrictions in the range, which may lead to so-called ‘range anxiety’ of drivers. Nonetheless, the race to electrify the transport sector is speeding up. Significantly, Volvo, the Chinese-owned Swedish car manufacturer, announced in June 2017 that all its cars built after 2019 would be hybrid or purely electric, the first major automotive firm to do so (Vaughan 2017). Bloomberg New Energy Finance have revised their forecasts and have suggested that, by 2040, 57 per cent of all

new car sales will be electric and that electric vehicles (EVs) are expected to be at parity with internal combustion vehicles by the mid-2020s in most markets (BNEF 2019). However, some countries are likely to move much quicker than the BNEF global average, with France and the United Kingdom announcing that they will ban the sale of petrol and diesel cars by 2040 (Chrisafis & Vaughan 2017). The rollout of electric vehicles will have profound impact on the power sector, through increased and flexible demand, cheaper electric storage technology, and the cross-over between actors in the utility and car manufacturing markets. Directly competing with premium EV manufacturer Tesla, traditional car producers such as BMW, Honda, and Nissan have already started selling household-level storage units, both to capitalise on their existing battery research, but also as a potential use for second-life batteries.³

This combined potential use has resulted in overall cost reduction in lithium batteries that are in line with those seen in the wind and solar PV sectors. The cost of the latest electric vehicle by car manufacturer Tesla, which entered production in 2017, has costs of US\$190 per kWh (Voelcker 2016), BNEF expect that costs will continue to decline reaching as low as US\$70 per kWh by 2030 (BNEF 2018). In the power sector, the costs for consumer level (Lambert 2016) or grid level storage are also falling fast, helping to accelerate their rate of deployment.

Progress in developing and commercialising new storage technologies, in particular solid-state batteries with a higher energy intensity than lithium-ion batteries and less use of scarce raw materials, is likely to accelerate the usage of batteries not only in automobiles, but also in applications around the smart home (Forschungszentrum Juelich 2018).

1.4 Decoupling growth and energy intensity via renewables and energy efficiency

Renewable deployment and storage technologies must go hand in hand with energy efficiency, if the system is to meet overall objectives of decarbonisation. The developments in energy demand vary hugely across the world's economies. The most striking feature in recent decades has been the increase in consumption in China and India, as can be seen in Figure 3. Although China's consumption is now three times larger than it was at the turn of the century, the overall growth rates seem to decrease, which is the case for energy, as seen in the graphic, but also for electricity. While the growth in India has been slower, there is currently no tapering off, with an expectation that by 2035 it will exceed that of China's (BP 2017).

³ Once batteries have degraded to some 80 per cent of their capacity, they may longer be suitable for vehicle usage, but may still be suitable to stationary storage where size and weight are no longer critical factors.

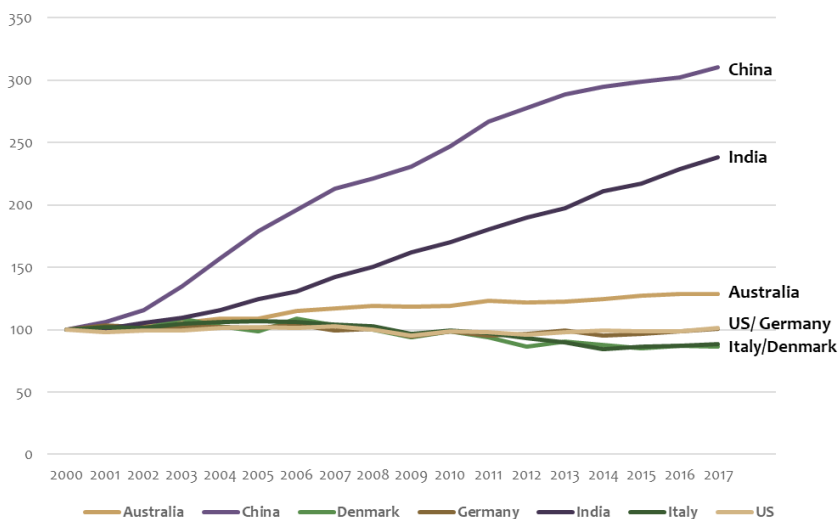


Figure 3: Relative increase in energy consumption in selected countries.

Source: BP Statistic Review (2018).

The energy intensity of the global economy is decreasing due to technological progress and systemic changes. Despite rising GDPs in many OECD countries, demand for energy and electricity are stable or falling, also because of structural changes in their economies – with less reliance on energy-intensive industries and a shift to services and digital production, as is shown in Figure 4.

In emerging economies, increase in energy demand has slowed significantly, mainly due to improved efficiencies, a reduced rate of infrastructure construction, for example, use of cement, and to some extent the increasing role of the service sector.

1.5 Value creation with decentralised renewable energy generation

Many countries still rely on a fully regulated electricity supply industry, often with vertically integrated utilities and a single-buyer model. For these countries, one driver for a stronger push towards decentralised supply structures may be motivated by over-arching policy objectives, namely local value creation and employment.

IRENA estimate that in 2016 renewable energy employed 9.8 million people, of which 3.1 million were in photovoltaics sectors and 1.2 million in wind power. Globally, China accounts for 3.6 million of the global jobs, of which solar PV accounted for 2.0 million. Within the sector, 1.3 million were for the

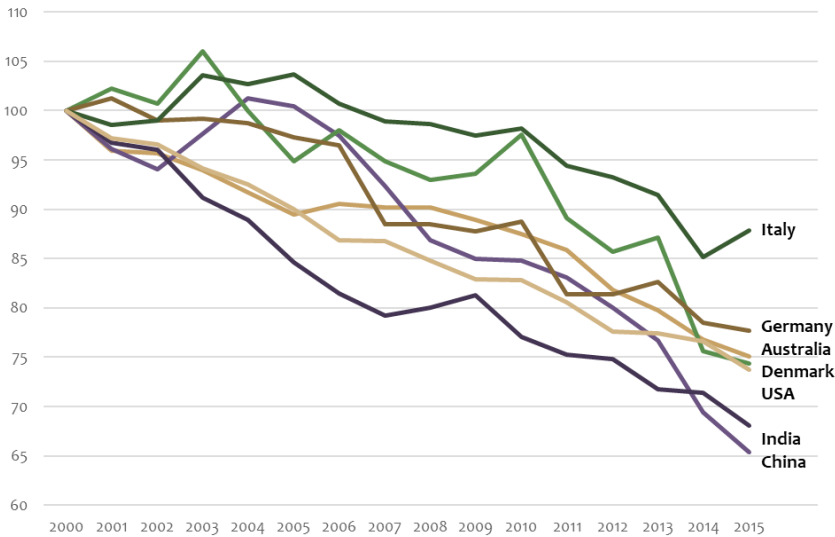


Figure 4: Relative change in energy intensities 2000–2015.

Source: World Bank (2018).

manufacturing of the PV panels, with 635,000 for construction and installation and 26,000 for operation and maintenance (IRENA 2017a). In Bangladesh, solar photovoltaics accounted for 140,000 jobs (*ibid.*). On a global basis across the value chain of a medium sized solar installation (50 MW), 22 per cent of the jobs are related to construction, while 17 per cent are in the installation, and 56 per cent in the operation and maintenance (IRENA 2017b).

An analysis of the US Department of Energy reveals that employment in the solar and wind industries totalled 374,000 and 102,000 individuals, respectively, out of a total workforce of 1.9 million in electric power generation and fuels technologies. Compared to 2015, employment in solar and wind industries increased by 25 per cent and 32 per cent, respectively, in 2016 (US Department of Energy 2017). If these figures are combined with the energy output by technology, they translate into 7724 MW hours per worker in the case of coal, 3812 MW hours per worker for natural gas, and 98 MW hours per worker for solar (Perry 2017). As Perry states, ‘to produce the same amount of electric power as just one coal worker would require two natural gas workers and an amazingly high 79 solar workers’ (*ibid.*) Perry interprets these comparative figures as an indicator for the lack of productivity in generating electricity from renewable resources, but if a government’s emphasis is on communal value creation, the new technologies offer unprecedented opportunities for local employment.

For the year 2012, the independent research institute IÖW investigated the impact of renewable energies on local value creation in Germany. With 36 per

cent, the manufacturing of components has the highest overall share in value creation, but this activity does only marginally take place on the municipal or regional level. However, the other elements of value creation, including planning and installation (13 per cent), operation and maintenance (23 per cent), trading (6 per cent), and revenues for owners (22 per cent), are strongly tied to the location of the installations: ‘The direct value added by renewable energies in Germany in 2012 adds up to 16.9 billion EUR with a municipal value added of around 11.1 billion EUR. Therefore 66 per cent of the total value added in the Federal Republic benefit local communities. In addition to that, nearly 380,000 jobs were created in 2012 by renewable energy in Germany’ (Aretz et al. 2013).

In off-grid locations, for example in Sub-Saharan Africa, the effects of value creation by decentralised supply may be even more pronounced, because they may not only contain the direct financial benefits for local communities, technicians, and owners of the installations, but may also include indirect effects. For example, they may positively affect quality of life in impoverished rural neighbourhoods, thus reducing urban migration and brain drain. In Chapter 3, the business models of start-ups Mobisol, Solarkiosk, and SolShare are presented, which target off-grid communities and enhance the local economy.

1.6 Digitalisation as enabler of the smart grid and new business models

In all facets of our lives we have entered the digital age. Not only communication, social interaction, and entertainment, but also shopping via the internet, the smart home with assisted living, e-government, or individual mobility with autonomous and connected cars. New information technologies and systems are revolutionising the energy sector, too, through the generation of individual data and the ability to process and analyse it, to the opportunities for machine learning, improving energy performance, and the increasing use of distributed ledger technologies, in particular Blockchain.

While the electricity supply industry has been slow to become aware of the opportunities and threats that these data management technologies can bring, the degree of interest and speed at which pilots are being undertaken indicate that rapid change is likely. Predictive maintenance of devices, such as turbines in thermal power plants, and more precise forecasts of consumption patterns have already become reality. The next step for data management will be to integrate micro-producers of electricity – so-called prosumers – into the balancing of the distribution network.

The rollout of smart meters and the installation of smart devices, such as sensors, in transmission and distribution networks is rapidly increasing the volume of information and the ability to process this. On average, a smart meter recording every 15 minutes transmits 400 MB of data each year. This information serves as an enabler of new markets, allowing businesses to collect,

anonymise, and analyse it, to potentially increase efficiency, better match supply with demand, and also – vice versa – enable demand to increasingly match variable supply.

However, smart meters and the linking of a wide range of electronic devices raises security concerns, specifically over privacy implications, despite suggestions that these fears maybe over-stated (Wang & Lewandowski 2016; Burger, Trbovich & Weinmann 2018).

Machine learning, whereby computers can improve their decision-making capabilities with minimal human intervention, has been part of the development of information technologies since the 1950s. However, the success of its usage and its potential have only been recently widely recognised in the energy sector. For example, machine learning is envisaged to improve the efficiency of generation, both conventional and renewable (Murgia & Thomas 2017). By machine learning with their Deep Mind computer power, Google estimates that it saves 40 per cent of consumption by optimising the efficiency of operation and predicting future data and energy usage. Information technology has become a major consumer of energy, but Google claims that because of super-efficient servers and rapid improvements in computer power they have increased the level of computer power they can produce per unit of energy consumed by 3.5 times over the last five years (Deepmind 2016).

Blockchain may be another source of digital disruption of the energy sector. It is a distributed database of data records that links transactions to each other, thereby providing transparency. Blocks are verified by a distributed network of computers. Transactions are encrypted. This cuts out the middlemen, allowing not only payment transactions but also smart contracts, the technology might provide a basis to embed prosumers into the energy system and deal with the resulting increasing complexity by reducing process costs and enabling platforms for smart contracts beyond a single energy provider (Burger et al. 2016; PwC 2016).

The above-mentioned key trends of competitiveness of renewables, the rising role of decentralised supply and storage, decoupling growth and energy intensity, enhancing local value creation, and digitalisation as enabler of smart grids and new business models describe the uncertainty policy makers and company leaders are facing. By looking at cases of country transformations and business models beyond subsidies, the next two chapters build a basis and guide through this uncertainty, including the necessary changes for governance, as introduced in the next chapter.

1.7 References

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