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International Renewable Energy Agency

THE RENEWABLE SPRING

The interplay between finance and policy in the energy transition

TECHNICAL PAPER 3/2021

BY KINGSMILL BOND

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1 CONCLUSIONS

The energy transition is a technology revolution which will continue to attract capital and build its own momentum. Policy makers who wish to drive rapid change need to put in place the right enabling environment, and capital will flow.

Technology revolutions follow a well-trodden path. Over the past 200 years, there have been five key technology revolutions, each with four phases that are analogous to the four seasons. The energy transition is the sixth technology revolution, and we are in the springtime of renewables.

Capital is attracted to technology transitions. Capital tends to flow to the areas of growth and opportunity associated with the start of technology revolutions. As a result, there is plenty of capital available.

Financial markets themselves draw forward change. As capital moves, it speeds up the process of change by allocating new capital to growth industries and removing it from those in decline.

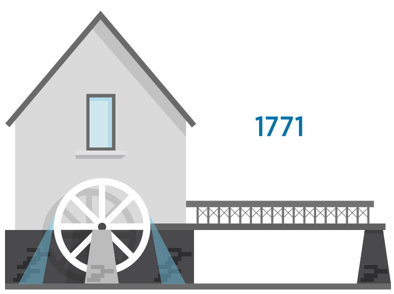
Financial markets are signalling an energy transition. Financial markets are signalling that we are in the first phase of the energy transition, with spectacular stock market outperformance of new energy sectors and the underperformance of the fossil fuel sector.

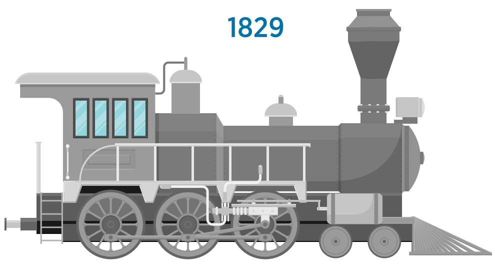
Policy makers can tap this enthusiasm. Wise policy makers are putting into place the necessary institutional framework to tap into this capital and accelerate their own energy system transition. The key tools are understood for electricity (auctions, targets, open systems and so on) and can be applied to other sectors.

The energy transition is sequenced by country and sector. Electricity is the lead sector, followed by transport. Northern Europe and the People's Republic of China are the leading locations. Although everywhere is different, most countries can take inspiration and guidance from the experience of the leaders.

Push factors give way to pull factors. At the start of the transition, policy makers need to focus on push factors, which give regulatory support, such as targets and subsidies. But as costs fall, so they can focus on pull factors to harness the power of the market such as establishing a level playing field and ensuring that polluters pay.

There will be some laggards. In around 20% of the world, vested interests may be able to hold back the energy transition. This will not hold back the global shift.





The five main technology revolutions

2 THE NATURE OF TECHNOLOGY REVOLUTIONS

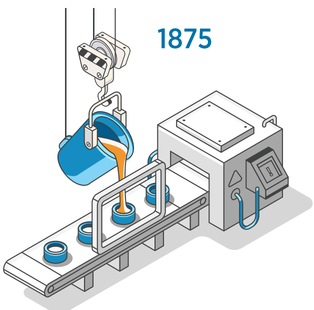
This paper sets set out below a brief overview of technology revolutions and how they interact with financial markets. It argues that there have been five major technology transitions over the last 200 years, and that the energy transition should be seen as the sixth one.[1] It notes that capital has tended to flow to new growth technologies, and that capital is now flowing rapidly into the new energy technologies that are driving change.

2.1 THE FIVE MAIN TECHNOLOGY REVOLUTIONS

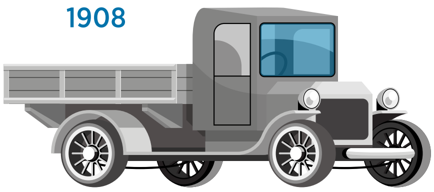
According to the academic Carlota Perez,[2] there have been five main technology revolutions since the eighteenth century, one every 50 years or so. Each one has been characterised by major breakthrough new technologies with a significant increase in productivity and rapidly falling costs. They have been driven by new players, and characterised by a number of different technologies on positive feedback loops. For example, more railways meant more coal transportation which led to lower costs for the railways and lower coal costs. Change has been fast and revolutionary, and driven by capital flows to areas of growth. Each technology revolution has resulted in a new techno-economic paradigm.

The five highlighted by Perez[3] are as below:

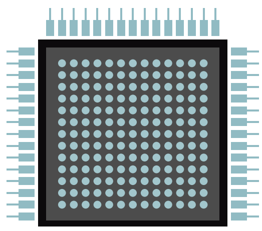
- **The Industrial Revolution.** The period after 1771 when industrialisation took off in Britain. The trigger was the opening of the Arkwright mill.
- **The age of steam and railways.** The period after 1829 when steam and railways drove a new wave of innovation The trigger was the test of the Rocket steam engine.
- **The age of steel, electricity and heavy engineering.** From 1875 and led by the US and Germany. The trigger was the opening of the Carnegie Bessemer steel plant in Pittsburgh.
- **The age of oil, cars and mass production.** Led by the US after 1908. The trigger was the first Model T being produced in Michigan.
- **The age of information and telecoms.** Led by the US after 1971. The trigger was the launch of the Intel processor.



1875



1908



1971

[1] It is worth noting that this transition is also driven by climate necessity and policy action. Which means it is both more urgent and faster.
[2] Source: Technology revolutions and financial capital, Perez, 2002
[3] In line with Kondratiev wave analysis

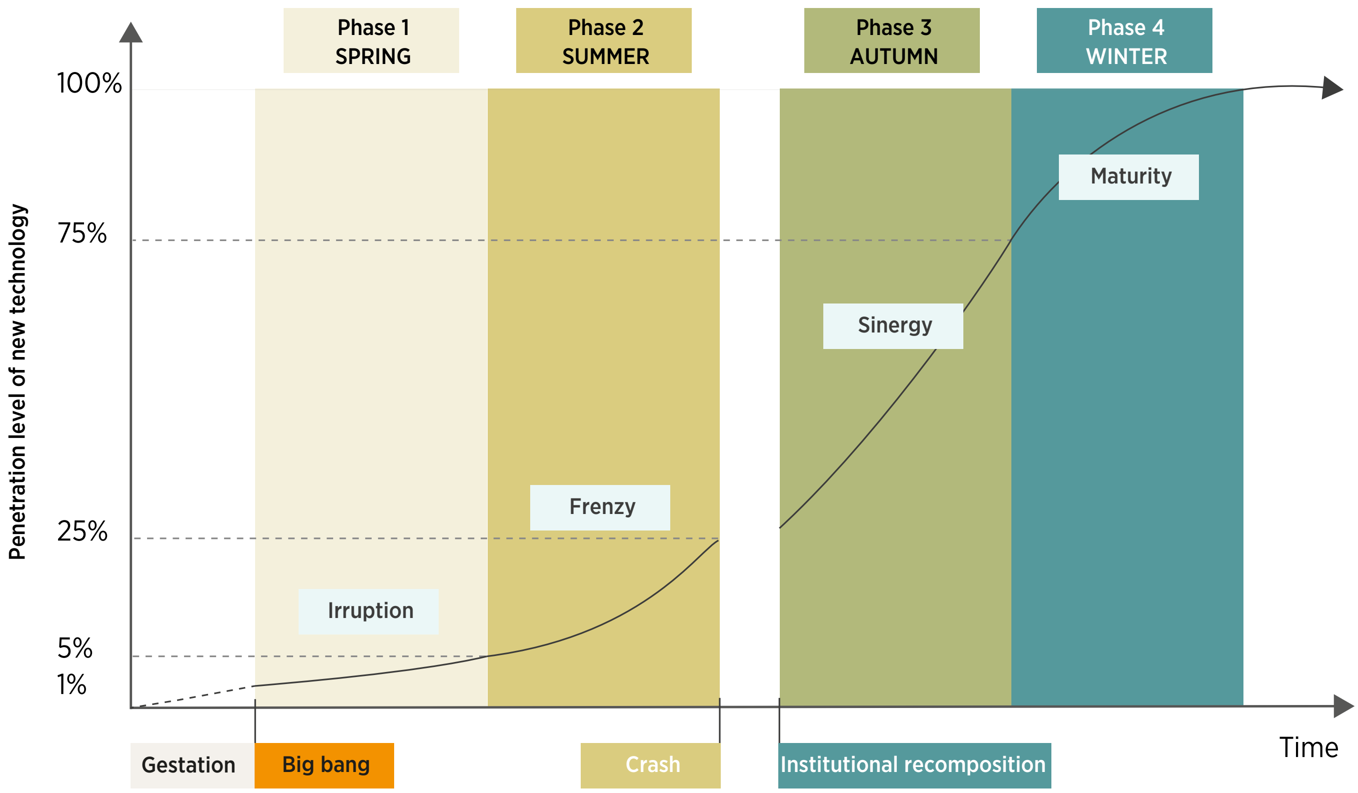
2.2 THE FOUR PHASES OF CHANGE

Each of these revolutions has had a gestation period (up to around 1% market share of sales) where ideas were tested, and the best ones succeeded. Beyond the gestation period, there have then been four main phases, each one lasting 10 to 15 years. Below is listed the characterisation made by Perez for these phases, with a season and rough market share estimates ascribed to each.

- **Irruption**. The *spring* of the new technology, where the market share moves beyond the 1% level and up to around 5% penetration. This is the period when the new technology becomes cost-competitive and starts to grow rapidly. It is a period of fast growth and fast innovation.
- **Frenzy**. The *summer* of the new technology where the market share moves from 5% to around 25%. This is a period of fast diffusion, where financial capital drives the build-up of new infrastructure. Because capital moves faster than new options are created, this period tends to end in bubbles.
- **Synergy**. At the end of the period of frenzy there is some event which catalyses a collapse of the financial bubble. This is followed by a turning point when the required regulatory changes are made to facilitate the further expansion of the new technology. This is the period when the full flourishing of the technology occurs. Perhaps best characterised as the *autumn* of the new technology, where the market share moves from 25% to 75%.
- **Maturity**. Eventually the new technology reaches maturity and is disrupted in turn as the cycle begins again. This is, of course, the *winter* of the technology.

One reason it is helpful to think in these terms is that a large part of the debate about the future of the energy system has been about what happens in the final phase. How do we get renewable electricity from 80% of electricity generation to 100%, for example? It is much more helpful to think about the spring phase that we are in today.

Figure 1: The phases of the technology surge



Source: Adapted from Perez (2002).

It is important not to confuse these four phases with the oft-used Gartner hype cycle (Gartner, 2021). The Gartner hype cycle refers very specifically to market reactions to technologies which are moving from the gestation phase to the irruption phase. It tends to play out over a much shorter time period, and therefore it is an appropriate tool for earlier-stage technologies such as green hydrogen or carbon-free cement.

2.3 CAPITAL AND TECHNOLOGY REVOLUTIONS

The key point is that financial markets see the most action at the start of technology shifts. This paper shows that capital flows to technology revolutions in the hope of the profit which is expected from growth and opportunity, and then notes that financial markets create their own momentum for change, a process known as reflexivity.

If capital is like water, then economics is like gravity; capital will flow to where the economic opportunity lies. So, as costs of new energy technologies fall, so the balance tilts in favour of new technology. Capital flows to the opportunity as illustrated below.

Capital finances opportunity

Perez makes a very helpful distinction between financial capital and industrial capital. Financial capital (a share in a company) is able to move at the click of a button, while industrial capital (a factory) tends to be linked to the incumbent system.

In the very early stages of new technologies, investors do not know which technology will succeed, and this is why innovation is most often done by entrepreneurs and investors. However, eventually, costs fall such that a commercial opportunity is clear. The role of financial capital in the four stages is then:

- **Irruption – spring**. Financial capital is constantly searching for new growth opportunities. As a result, it will finance new technology opportunities at a relatively early stage. British capital, for example, financed the buildout of railways and then steel in the United States at a very early stage of development. In more recent times, investors have financed the buildout of the internet or the profitless growth of Amazon and Uber.
- **Frenzy – summer**. A time eventually comes when many investors are allocating their capital to the great new technology opportunity. But there are too few investment opportunities. A frenzy results, and causes financial bubbles. The classic example is the internet bubble at the end of 1990s.
- **Synergy – autumn**. After the shake-out that tends to characterise the end of the frenzy, investors understand the new technology and figure out how to put it to work and make profits. Regulatory structures change to accommodate the new technology, and deployment continues albeit at a less frenzied pace. This is a less exciting time, but one of solid returns.
- **Maturity – winter**. Eventually the new infrastructure is built out, and capital moves on to the next big thing.

Within financial markets, the first movers will often be hedge funds and other highly nimble financial market actors who are open to new ideas, more comfortable with higher risks, and very sensitive to changing opportunities. As the story starts to take hold, it is picked up by the larger pools of capital managed by more mainstream actors.

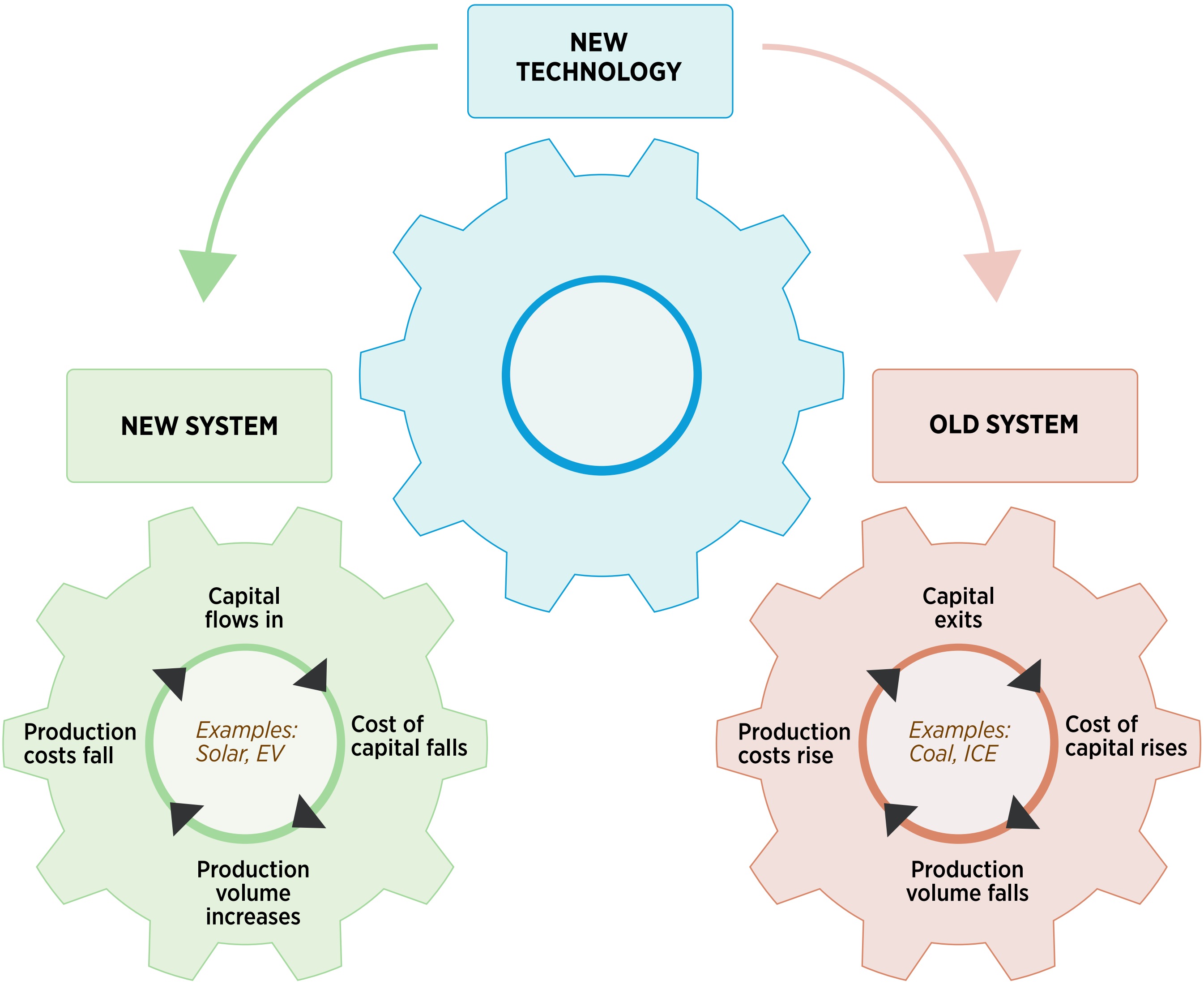
Capital drives change – reflexivity

As capital flows to the areas of opportunity, it then tends to speed up the process of change. This is the process known as reflexivity, made famous by George Soros (2003), and then highlighted in more recent times by Larry Fink (BlackRock, 2020), who noted the tendency of financial markets to bring change forward.

As Carbon Tracker noted in "2020 vision" (2018), financial markets tend to derate old sectors shortly before peak demand.

The story is simple; the framework is laid out in Figure 2. As a new technology establishes itself, investors allocate capital into companies which lead the deployment of the new technology and exit companies that operate the old technology. Two feedback loops then result across many areas, as examined in more detail by Carbon Tracker in *"Spiralling disruption"* (2021c).

Figure 2: Reflexivity and technology



Source: Adapted from Soros (2003)

Note: EV = electric vehicle; ICE = internal combustion engine.

- **Positive feedback loop**. As capital flows into the new technology, so the cost of capital falls. As the cost of capital falls, so companies are able to raise capital more easily to expand production. And as they expand production, costs fall faster. And as costs fall, so new capital is attracted into the new opportunity. The success of internet stocks is one classic example at the end of the 1990s. But a more recent example is the ability of Tesla to raise very large amounts of capital which it can then deploy in building more battery factories. Which in turn drives the price of batteries down, therefore stimulating demand for more cars. Similarly, renewables developers are able to raise capital and in turn drive down the costs of renewables, making it easier for them to grow, and attracting in more capital.
- **Negative feedback loop**. The incumbent industry of course faces the opposite dynamic. As investors lose faith in the sector, so capital exits it very early. As capital exits, so incumbents struggle to raise capital. They are then forced to reduce production, meaning that they face write-downs and higher unit costs as total cost is spread over less volume. This then forces them to curtail production, leading to a loss of investor confidence and lower share prices. This is pretty much the environment that has been faced by large parts of the legacy retail sector since the rise of the internet, and is the environment that now faces legacy car companies and fossil fuel companies. It is striking that brokers such as Morgan Stanley already ascribe minimal value to the legacy carmaking operations of the incumbent car companies such as General Motors and Ford, at a time when electric vehicle (EV) sales are only 4% of the total and the EV fleet is 1% of the global car fleet.

Incumbents rarely react in time to the technology shift, a phenomenon explored in detail by Christensen in his famous work *The Innovator's Dilemma* (1997). The European electricity sector failed to forecast peak fossil fuel electricity in 2007; the coal industry failed to forecast peak coal demand in 2013; GE did not foresee the rapid fall in gas turbine demand when it bought Alstom in 2014; the car sector did not foresee peak internal combustion engine (ICE) demand in 2017; and until 2020 the oil industry did not foresee a looming peak in oil demand.

3 THE ENERGY TRANSITION AS A TECHNOLOGY REVOLUTION

3.1 WHERE WE STAND TODAY

Energy is the foundation technology upon which rests our society, and it was the exploitation of fossil fuels which enabled a fiftyfold increase in global energy demand in the period from 1800 to today (Morris, 2015). And now that energy system is undergoing a new revolution. It is well known that solar and wind have the technical potential to generate huge flows of energy, calculated by NREL as 900 petawatt hours (PWh) per year of wind (NREL, 2017) from onshore and offshore sources, and by the World Bank as 5 800 PWh per year of solar on accessible land (World Bank, 2020). Combined, these flows of energy are more than two orders of magnitude greater than the 27 PWh of electricity and 65 PWh of total energy the world consumed in 2019 (Carbon Tracker, 2021a).

The energy revolution has come about because the costs of solar, wind and batteries have fallen to levels which enable us to unlock their enormous potential. Data from Lazard (2020) for the United States, for example, indicate that the levelised cost of electricity (LCOE) of new solar photovoltaic (PV) is now USD 37 per megawatt hour (MWh), compared with new coal at USD 112/MWh or new gas at USD 59/MWh. And every indication is that renewable costs will continue to fall on learning curves whereby their costs fall by around 20% for every doubling in deployment (Farmer, 2016). These are also of course beneficial learning curves, so that each technology reinforces the other. As battery costs fall, so it becomes possible to have a rising share of solar and wind in the electricity system. As the demand for storage grows, so battery costs fall, enabling EV demand to rise.

It follows that the new energy revolution can be seen in the same light as the five great technology revolutions identified by Perez.

The electricity sector has been leading the change, followed a few years later by the transport sector (Figure 3). Solar and wind in 2020 were 9% of global electricity generation (and solar grew in 2020 at 21% and wind at 12%), and are thus in phase two. EVs have recently broken into phase 1, as their market share in 2020 was 4% of sales. Areas such as heavy industry are still in the gestation phase of change, where it is not yet clear which new carbon-free technology will be most successful. Hydrogen is in the gestation phase, but is quickly moving into the spring phase as electrolyser costs fall on learning curves. Solar and wind made up 4% of the primary energy supply in 2020 (and 47% of primary energy supply growth in 2019) (BP, 2020b), which is why this period is characterised as the springtime of the renewable technology revolution.

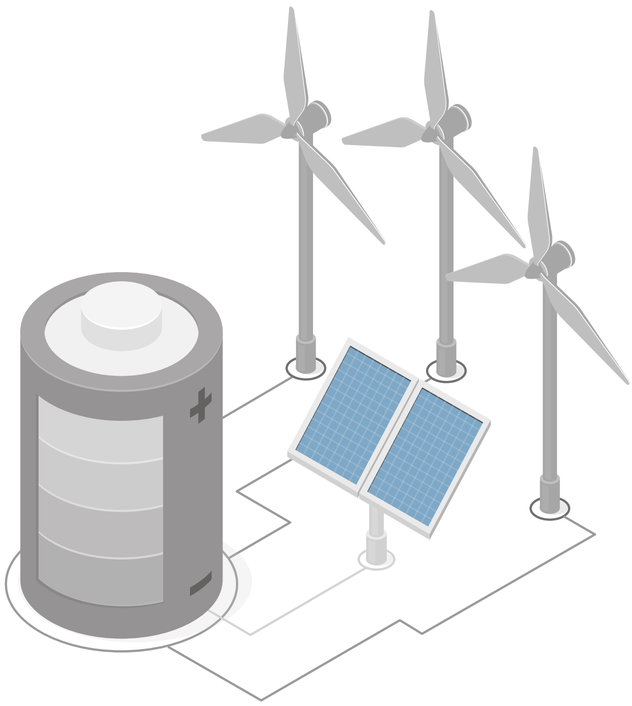
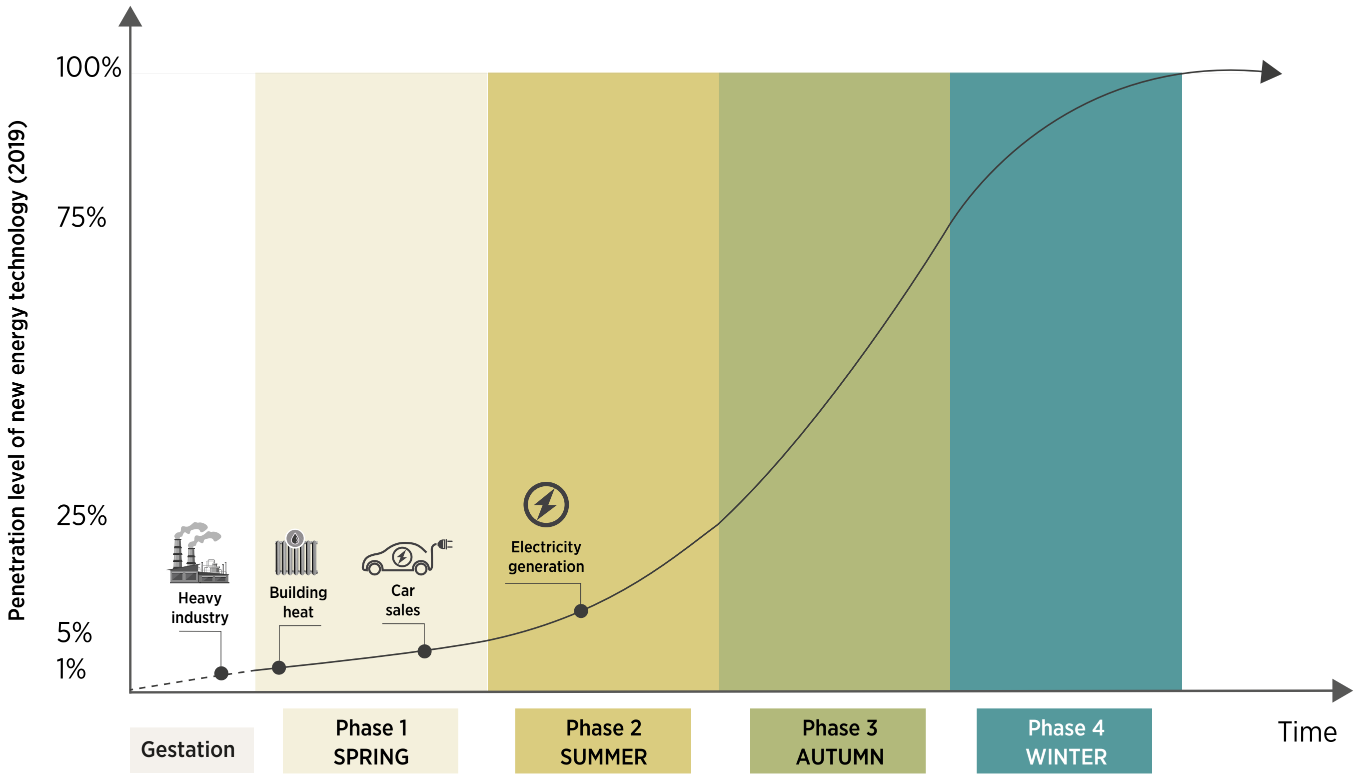


Figure 3: Sectors and the energy transition

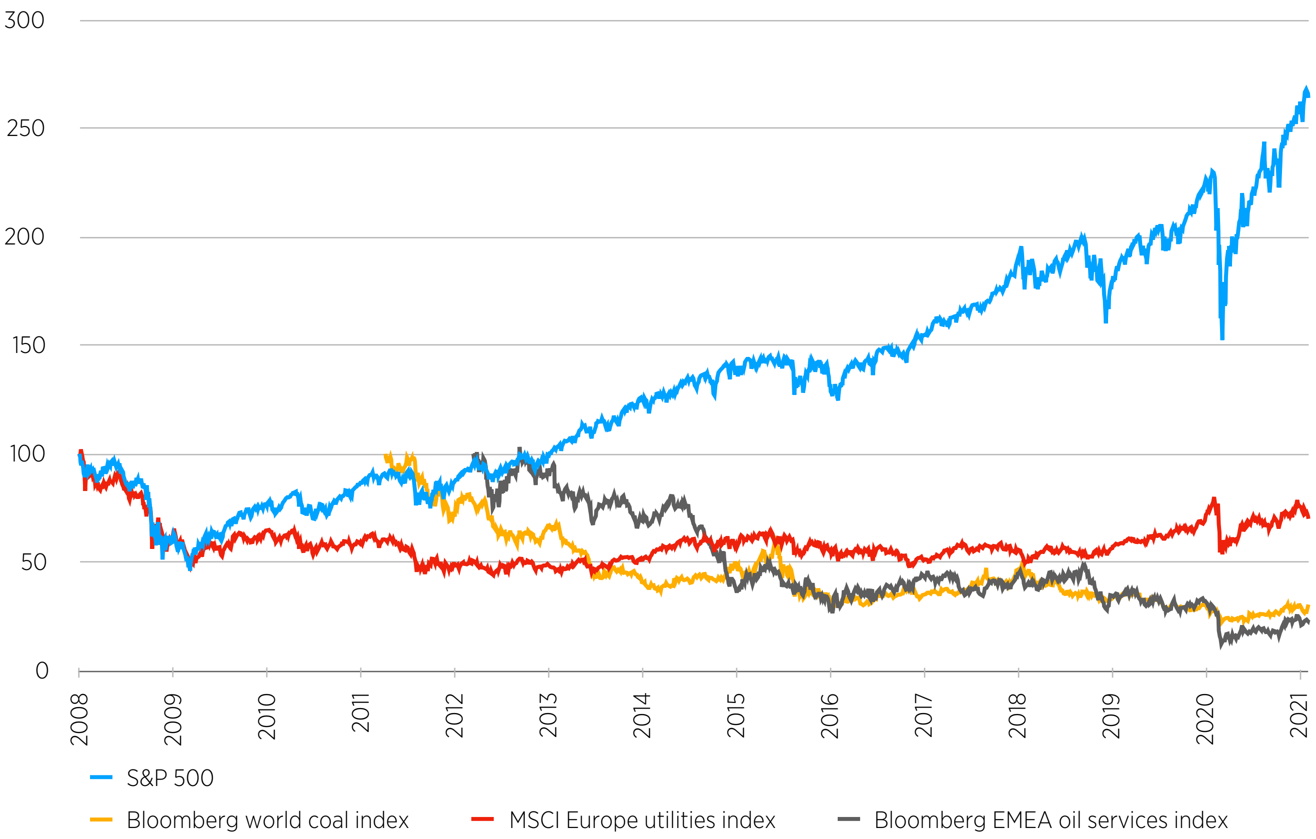


Source: Adapted from Perez (2002).

Figure 4: Energy sector as share of S&P 2010-2021

Source: Bloomberg (2021)

Figure 5: Fossil fuel subsector performance



Note: EMEA = Europe, Middle East and Africa; MSCI = Morgan Stanley Capital International.

Source: Bloomberg (2021).

Figure 6: Renewable energy stock performance: NEX Index

Source: Bloomberg (2021)

3.2 FINANCIAL MARKET PERFORMANCE

Financial markets have reacted as is typical in the irruption stage, with stock market underperformance by legacy companies and outperformance by new energy companies. The process of change was accelerated by the shock of COVID in 2020.

Derating of the old

Investors have been derating fossil fuel shares for almost a decade as they started to see the prospect of peaking demand for incumbents. One classic way to demonstrate this is to look at the share of the energy sector (which is mainly fossil fuel companies) as a share of the S&P Index. The energy sector made up 13% of the index in 2011, but has fallen over the course of the decade to below 3% (Figure 4).

The energy transition is of course occurring in phases, so the derating of incumbents takes place in the most vulnerable areas first. The European electricity sector peaked in 2007, suffered in the 2008 financial shock like all other sectors, but failed to recover as it became clear that demand for fossil fuel generation in Europe had peaked. The global coal sector peaked in 2011, before global coal demand peaked in 2013. And the oil services sector peaked in 2012, shortly before the 2014 peak in oil services demand (Figure 5).

Rerating of the new

The counterpart to this derating of the incumbents has been the rerating of the renewables sectors. Companies such as Tesla and BYD in the auto sector and Orsted and NextEra in electricity have enjoyed a very profound rerating over the last five years. The main renewable index (the WilderHill New Energy Global Innovation Index [NEX]) has been slowly trending up since 2016 but enjoyed a spectacular rerate in 2020 (Figure 6)

Supercharged by COVID

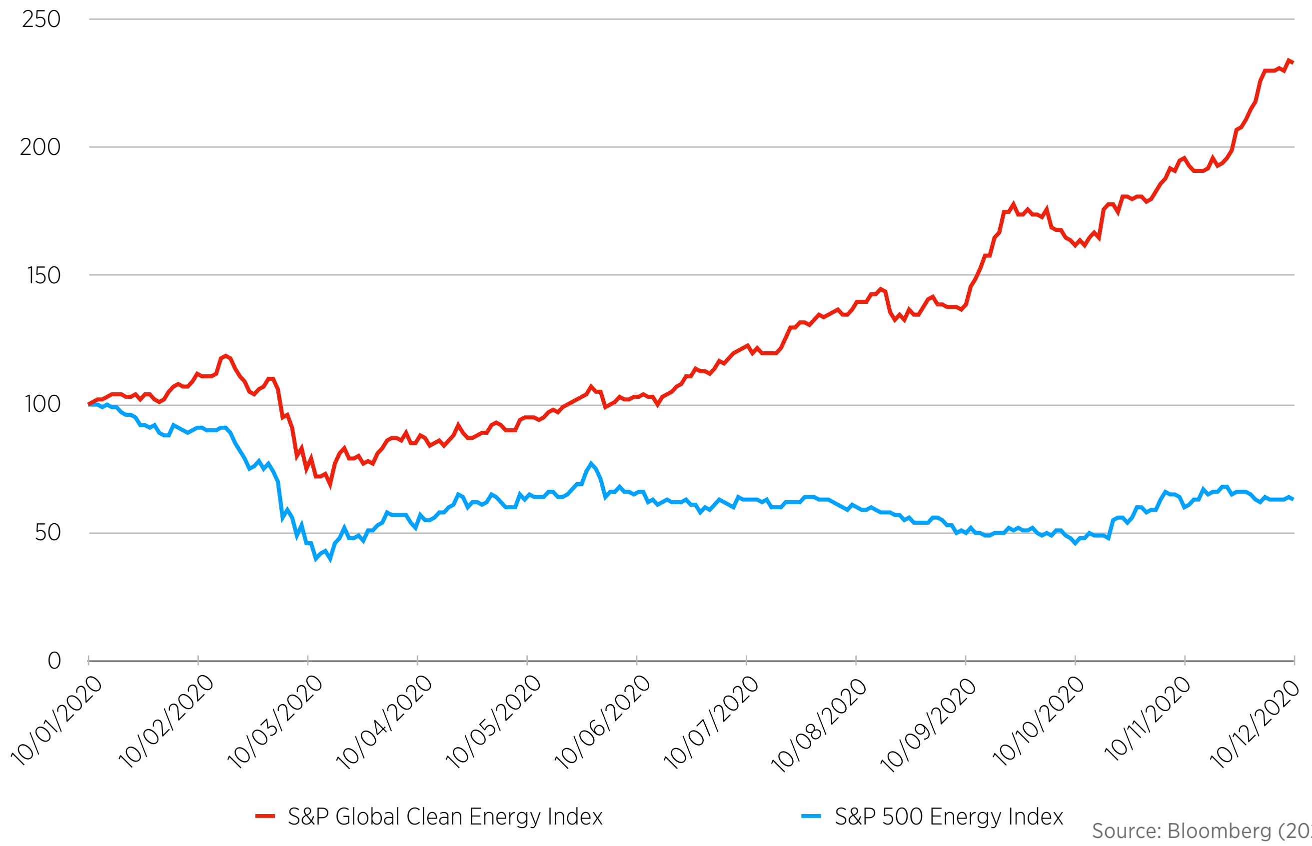
The rapid growth of renewables and the low growth of total energy demand mean that a number of commentators such as DNV and McKinsey were expecting peak fossil fuel demand in the 2020s. Any fast-growing challenger will be able to take the growth in a low-growth system at a fairly early stage simply because of the logic of maths (Carbon Tracker, 2018). For example, global coal demand peaked in 2013, global ICE demand peaked in 2017, and global demand for fossil fuels for electricity generation fell in 2019, implying a potential 2018 peak. In 2019, fossil fuels made up less than half the growth in demand for energy (BP, 2020a).

However, COVID has likely brought forward the moment of overall peak fossil fuel demand to 2019 because it has damaged demand for fossil fuels but not held back the growth of renewables.[4] By the time global energy demand returns to its 2019 levels, all of the growth is likely to come from renewables; this has led commentators such as DNVGL (2020) to bring forward their date of the expected global fossil fuel demand peak to 2019, and even the oil company BP (2020b) is now suggesting that 2019 was peak oil demand. Forecasters such as McKinsey now expect that fossil fuel demand has reached its plateau, with 2027 demand only 2% higher than that in 2019 (McKinsey, 2021).

The realisation of peaking demand has meant a dramatic acceleration in the financial market shift during 2020, which can be seen in the performance of the S&P indices in 2020.[5] The fossil-heavy energy index fell by 37%, and the clean energy index was up by 133% (Figure 7). As is well appreciated, there are a number of renewable energy stocks such as Plug Power and Tesla where performance has been even more spectacular.

As so often happens, the same analysts and forecasters who failed to see change coming are now foremost in calling this a green bubble. It is true to say that there are exuberant characteristics in parts of the new energy story, but this is again typical for the early stages of transitions. After all, the internet did not vanish after the collapse of the stock bubble in 2000; after a brief pause, the disruptive power of the internet accelerated to transform the global economy.

Figure 7: Performance of clean energy and fossil energy stocks in 2020



Source: Bloomberg (2021)

4 For example, in 2020 oil demand fell by 9%, coal demand by 4% and car demand by 16%, while solar generation increased by 21% and EV sales by 41%.
5 Some of the gains have been lost in 2021, but the 2020 recalibration is nevertheless notable.

3.3 WHAT NEXT

This report highlights below the power of exponential growth to drive change and to cut costs, meaning that the energy transition may be less difficult than many fear. It notes how capital is likely to flow to the opportunities, meaning that the challenge for policy makers is to set in place conditions to allow capital to flow rapidly.

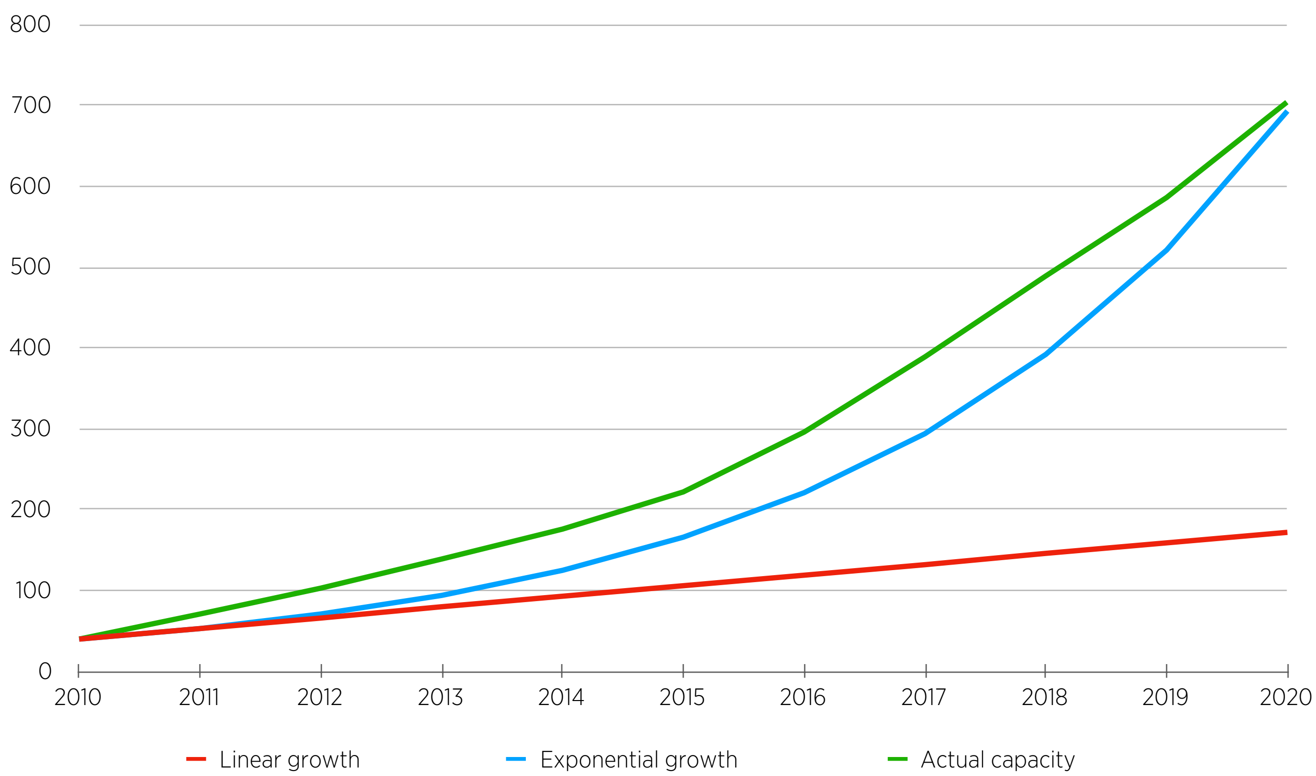
The power of exponential change

There are two main perspectives on the likely growth rate of new technologies: linear growth, and exponential growth. Linear growth is how most modelling is done, but renewable energy technologies have been characterised by exponential growth.

- **Linear growth** assumes that supply continues to grow at the same amount. So, if you start with 40 gigawatts (GW) of solar growing at 33%, then 13 GW of solar are installed the first year. If one assumes linear growth, then 13 GW is installed every year. As Auke Hoekstra has shown repeatedly on Twitter, this is famously how the International Energy Agency (IEA) has modelled the solar sector for many years.
- **Exponential growth** assumes that supply continues to grow at the same percentage. So, if you start with 40 GW of solar growing at 33%, then 13 GW are installed in the first year, but 18 GW in the second year and so on.

The gap is small initially, but soon grows to be enormous. It was, after all, Einstein who called exponential growth the most powerful force in the universe. The three graphs below start in 2010 at 40 GW: linear growth of 13 GW per annum (which is 33% growth in 2010); exponential growth of 33% per annum; and the actual amount of solar installed since 2010 (Figure 8). It is clear that solar has been growing on an exponential graph. Battery deployment and EV sales have also been on a similar (but faster) exponential growth curve.

Figure 8: The gap between linear and exponential growth: solar capacity in GW



Source: Actual capacity data from BP (2021).

The reason that this matters is that it is much more credible to achieve future renewable deployment levels when they are considered in exponential terms. For example, IRENA notes that to get to the 1.5°C Scenario, solar PV capacity in 2030 would need to be 5 200 GW (IRENA, 2021).

In 2020, global solar installations were 127 GW, and year-end cumulative installations were 707 GW. Linear forecasting implies that it would take 36 years of 127 GW annual installations to reach the IRENA 2030 target of 5 200 GW (Figure 9). However, exponential growth of 22% per year is required to get to the 2030 number in a decade, a growth rate which is achievable for a sector where annual capacity growth has averaged 33% a year for the last decade.

How much capital is required

A similar debate can be had when calculations are made about how much capital is required to finance the energy transition.

Linear forecasts assume costs remain at around the same levels as today. The energy transition thus looks very expensive.

Exponential forecasts assume that costs fall exponentially over time, as they have done for the last decade. The energy transition is then very affordable.

Figure 10 illustrates this with the capital for fixed costs that must be spent on solar capacity to reach the IRENA 1.5°C target of 14 036 GW of solar by 2050. It starts with the assumption of a fixed cost in 2019 of USD 1 per watt. With no cost falls, the total cost is over USD 13 trillion. If costs fall by 5-10% a year, the total cost will be USD 3-6 trillion.

Figure 9: Solar capacity (GW) at different growth rates

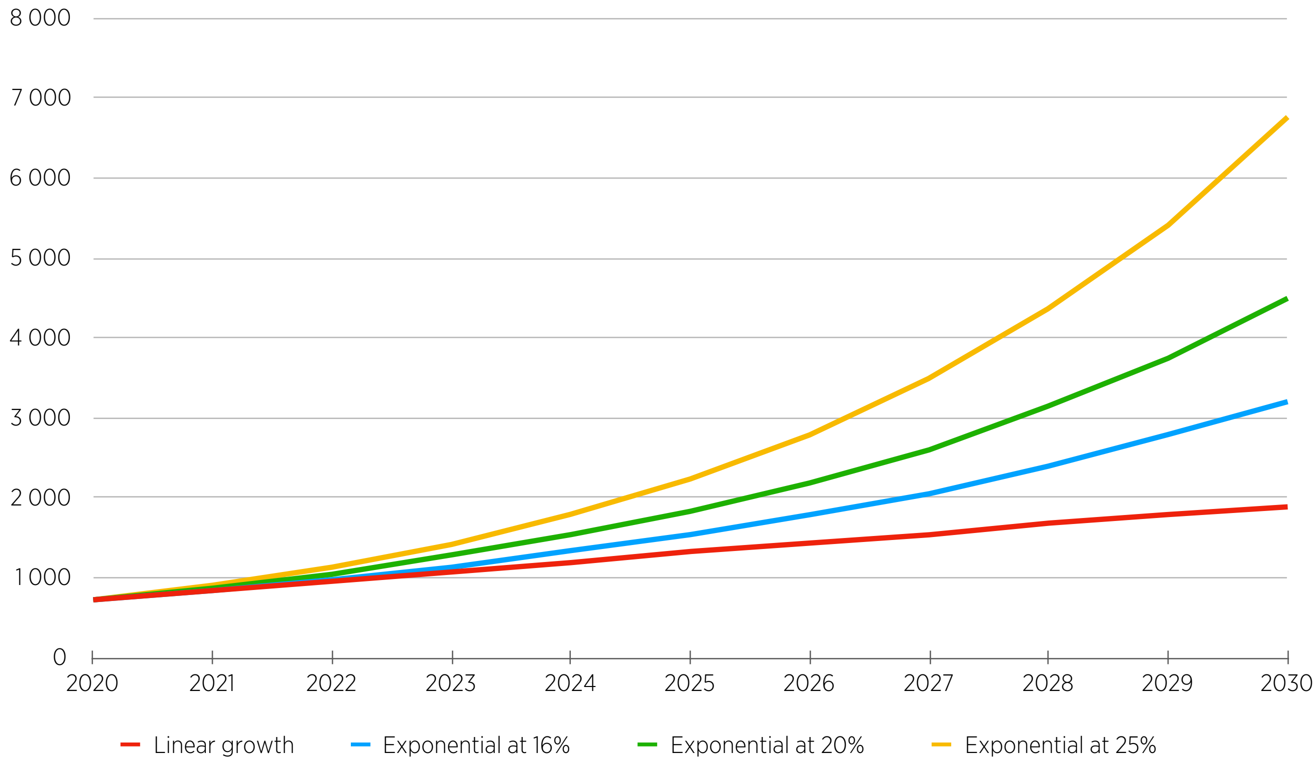
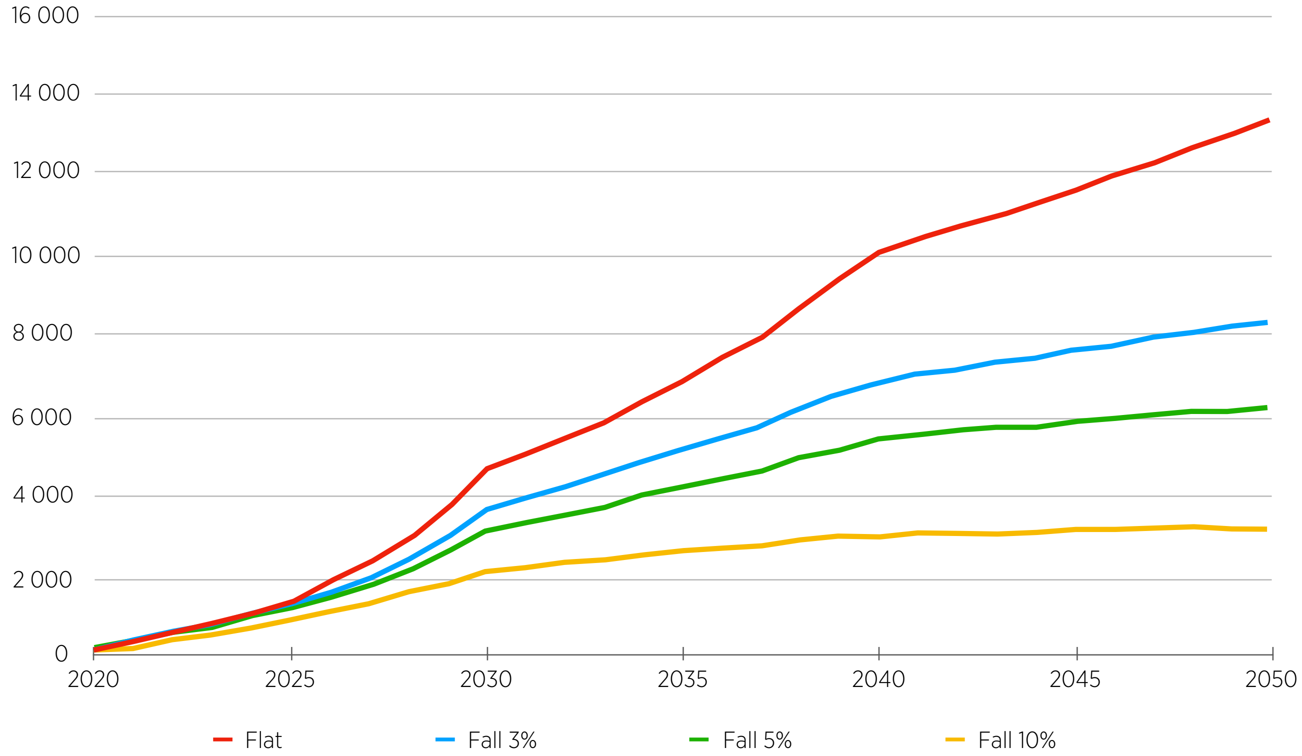
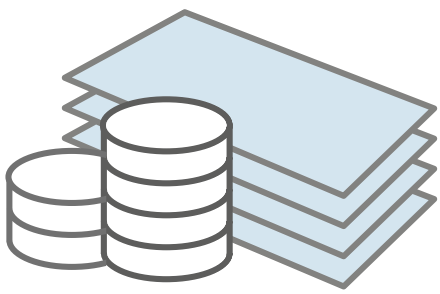


Figure 10: Cumulative capex on solar capacity fixed costs, 2020-50 (USD billion)



Over the last decade, the cost of electricity from solar in the United States has fallen by 17% every year and wind by 11% every year (Lazard, 2020). It has been shown by Doyne Farmer that these learning curves are likely to be maintained, so costs are likely to continue to fall (Farmer, 2016).

These learning curves are one of the key reasons that organisations such as IRENA, the Energy Transitions Commission (2020) and the Oxford Martin School (Way, 2020) calculate that the incremental cost of an energy transition is limited or negative, even before taking into account the costs of externalities.



Capital flows to opportunity

This paper has noted that technology revolutions are characterised by the willingness of capital to finance them. Even before the formation of modern capital markets, it was possible for very capital-intensive industries such as railways or steel to get access to capital. This is even more the case today in a world of extremely low interest rates and high growth from renewables.

The implication is therefore that capital will flow into renewable energy opportunities. Most developers note that there is more capital available than good investment opportunities. The implication for policy makers is clear. In the same way that the sun shines, so capital is available. To capture the energy of the sun you need a solar panel. And to capture the capital of investors you need a supportive policy regime. In its annual Climatescope report, BloombergNEF (2020) has perfectly captured the importance of policy. It notes, for example, that countries with supportive policies in place have attracted 16 times as much capital as those without.

4 HOW POLICY MAKERS CAN ATTRACT CAPITAL

As the reality and science of climate change shift domestic politics, and under the pressure of popular opinion, policy makers around the world are now looking to put in place policies to accelerate the energy transition. But there is also an emergent awareness among political leaders that future economic competitiveness, closely tied to the cost of energy, will crucially depend on whether their economies manage a timely and effective transition to the low-carbon solutions of the future. Against this backdrop, policy makers are increasingly wondering how they can attract the capital to finance the energy infrastructure and industries of the future.

There are many bodies which have set out in detail what policy makers need to do – see e.g. IRENA, *World Energy Transitions Outlook* (2021). The United Kingdom's Climate Change Committee has a series of detailed policy documents setting out what needs to be done (Hepburn et al., 2020). The Energy Transitions Commission (2020) highlights the need for a buildout of generation capacity, the establishment of a level playing field and investment in new technologies to solve the hard-to-solve sectors.

The Climate Finance Leadership Initiative (CFLI) has produced a report on attracting private climate finance to emerging markets, which highlights the importance of targets, auction and open systems (CFLI, 2020). And BloombergNEF (2020) has highlighted the importance of policy for the emerging markets. The disruption caused by COVID has also provided many opportunities for organisations such as IRENA (2020), the Smith School (Allan, 2020), or Climate Action Tracker (2020) to provide guidance to policy makers for plans to build back better after the crisis.

Of those points, perhaps the most important at present are to make polluters pay and to create a level playing field. Trying to run a carbon-limited system without a carbon tax is like trying to run a complex economic system without money; it will struggle to work (Carbon Tracker, 2020). This paper seeks below to add a couple of dimensions to this discussion insofar as they are relevant to the intersection among policy makers, financial markets and the energy transition.

4.1 CHANGE IS SEQUENCED BY SECTOR AND COUNTRY

Each country and sector is, of course, different. So policy needs to reflect where each country stands in terms of each sector and its own local circumstances. Nevertheless, there are some broad observations that can be made as below.

Sector

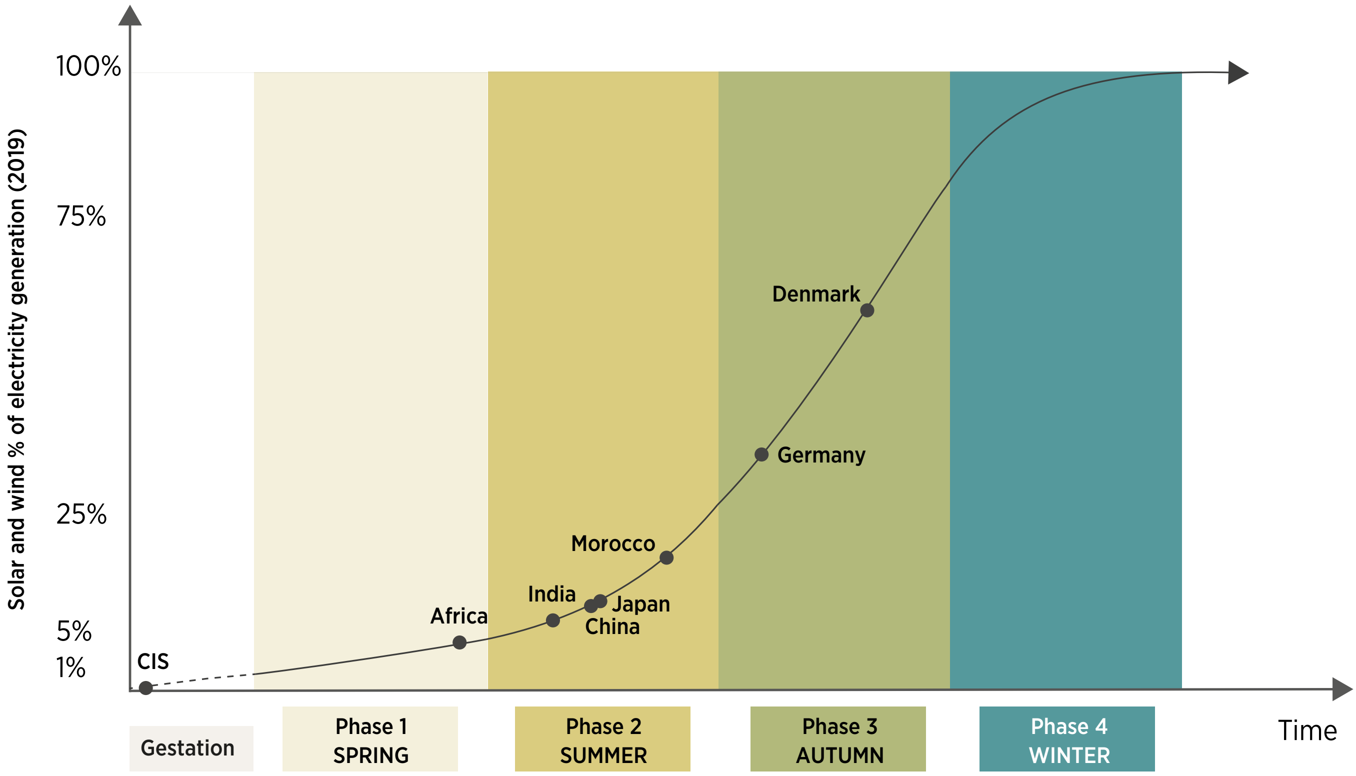
As set out above, electricity is at phase 1 or 2 in most counties. In transport most places are still in in phase 1. Industry and green hydrogen are still in the gestation phase, so the risks are much higher of choosing the wrong technology. If policy makers in cutting-edge markets are focused on the industry sector at present, then policy makers in most other countries should concentrate on the electricity sector first, followed by transportation.

Country

Most countries do not need to have cutting-edge policies. They can simply take inspiration and solutions from those countries which have already undertaken change.

And because of the carbon imperative, leading countries have a direct incentive to encourage laggards to shift their energy mix to low-carbon sectors. As a result, they are more likely to share technology and policy innovation.[6] For example, in the electricity sector, Denmark and Germany are leading change and moving up the ceiling of the possible level of integration of solar and wind into electricity markets (Figure 11). But most countries are at relatively low levels of penetration and do not need to reinvent the wheel.

Figure 11: Country sequencing



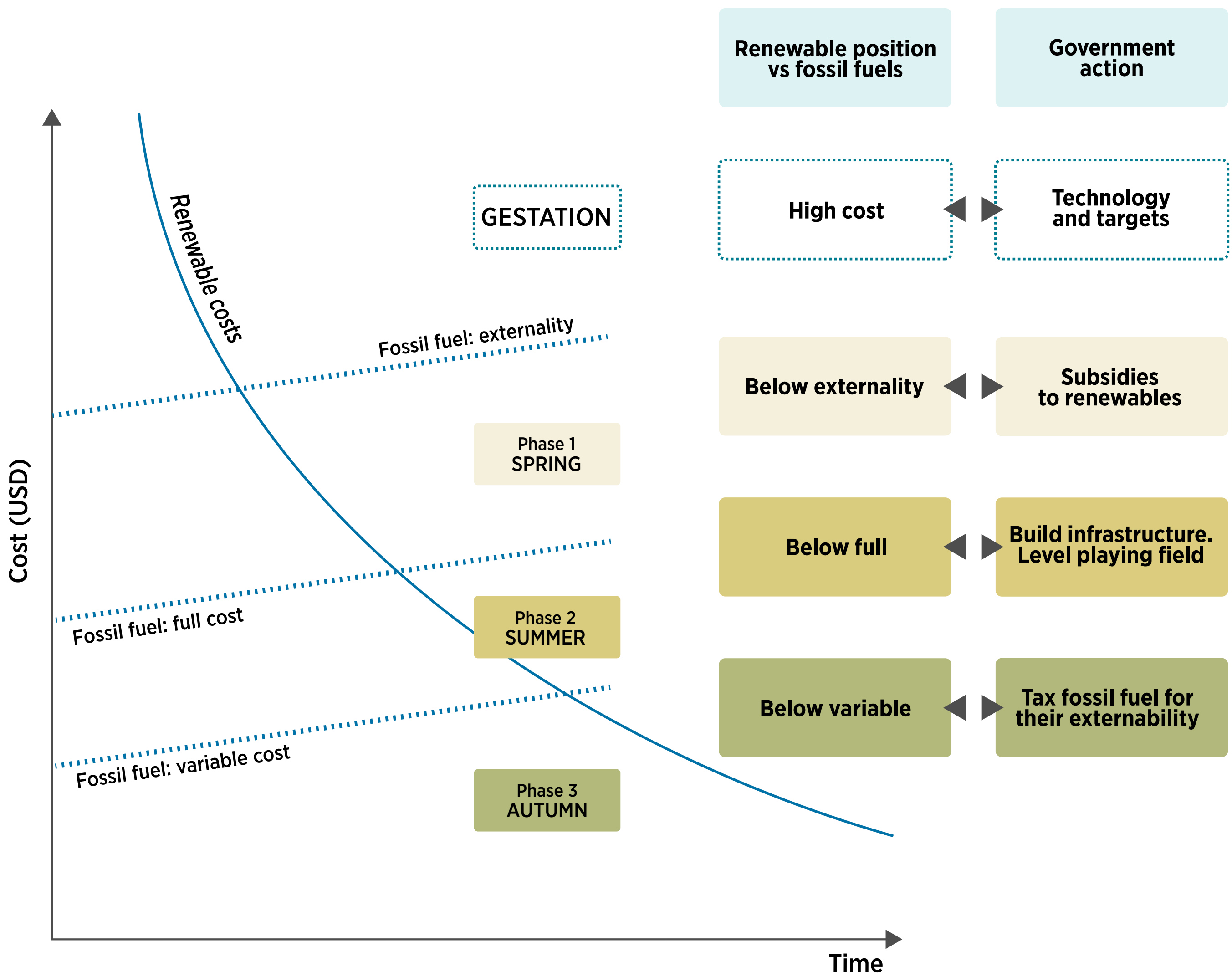
Note: CIS = Commonwealth of Independent States.

Source: Adapted from BP (2021).

[6] There are many examples of this such as the World Bank Energy Sector Management Assistance Programme (ESMAP). Although much more is needed, as noted by Arunabha Ghosh of the Council on Energy, Environment and Water (CEEW, 2019) in India.

In *"Reach for the sun"*, Carbon Tracker set out in more detail for the emerging markets the drivers of change and the barriers to change and concluded that the balance of forces in most countries favoured an energy transition (Carbon Tracker, 2021b). In its report *"How to retire early"*, the Rocky Mountain Institute (RMI, 2020) lays out the rapidly shifting economics of power generation around the world, moving in favor of renewables and the early retirement of existing coal fleets. In major coal and gas exporters and in fragile states, change will of course be more difficult. However, because these regions make up less than 20% of emerging market electricity demand, they are not large enough to hold back the global shift..

Figure 12: Cost levels and the opportunity set for policy makers



4.2 THE OPPORTUNITY SET DEPENDS ON THE COST LEVEL

As new energy technology costs fall, there are broadly four stages that policy makers can follow if they wish to support an energy transition. We illustrate this with Europe and the electricity sector.

- **High cost – technology innovation.** In the early stages, new energy costs are very high, and it is necessary to help form a market. The role of policy makers as pointed out by Mazzucato (2013) is to stimulate technology innovation and to create a market by setting out clear targets.
- **Below externality cost – bridge the gaps.** As costs fall, renewable costs get to a stage where they are higher than the total fossil alternative but in fact lower than fossil fuel costs when externalities are considered. At this point, policy makers should either tax the externality (better) or subsidise the new energy technologies.
- **Below fixed cost – build out infrastructure.** When renewable costs fall to below the fixed cost of the fossil fuel alternative, that means that it makes more sense economically to build new renewables than new fossil fuels. Policy makers need to concentrate on creating a level playing field.
- **Below variable cost - tax externalities.** When renewables costs fall below the variable costs of fossil fuels, then it makes financial sense to close down the existing fossil fuel assets. Moreover, there is no cost to consumers from taxing the externality as the incumbent cannot pass on the costs. At this point policy makers need both to tax the externality and to facilitate the exit of the pollutive technology. Crucially, this exit of the fossil fuel infrastructure needs to be accompanied by support for the workers in incumbent industries and actions to ensure a just transition.

Intelligent policy can drive positive feedback loops

Because capital is available for change, intelligent policy can drive positive feedback loops as examined by CFLI (2020). So, for example, targets can encourage companies to build EVs. Which drive down costs, which mean they build more. Auctions can increase competition, which drives down costs.

The real risk lies with the status quo

It may seem attractive for policy makers to plan for the continuity of the status quo. After all, that is what most incumbent forecasters tell you will happen. But the idea of business as usual has been wrong time and again in the energy transition because of the speed of cost falls. Given that costs are still falling it is therefore much more sensible to plan for a new world of opportunity of the lowest-cost energy sources. Who after all will take the risk to build fossil fuel infrastructure with a 30- to 40year life at the end of the fossil fuel era?

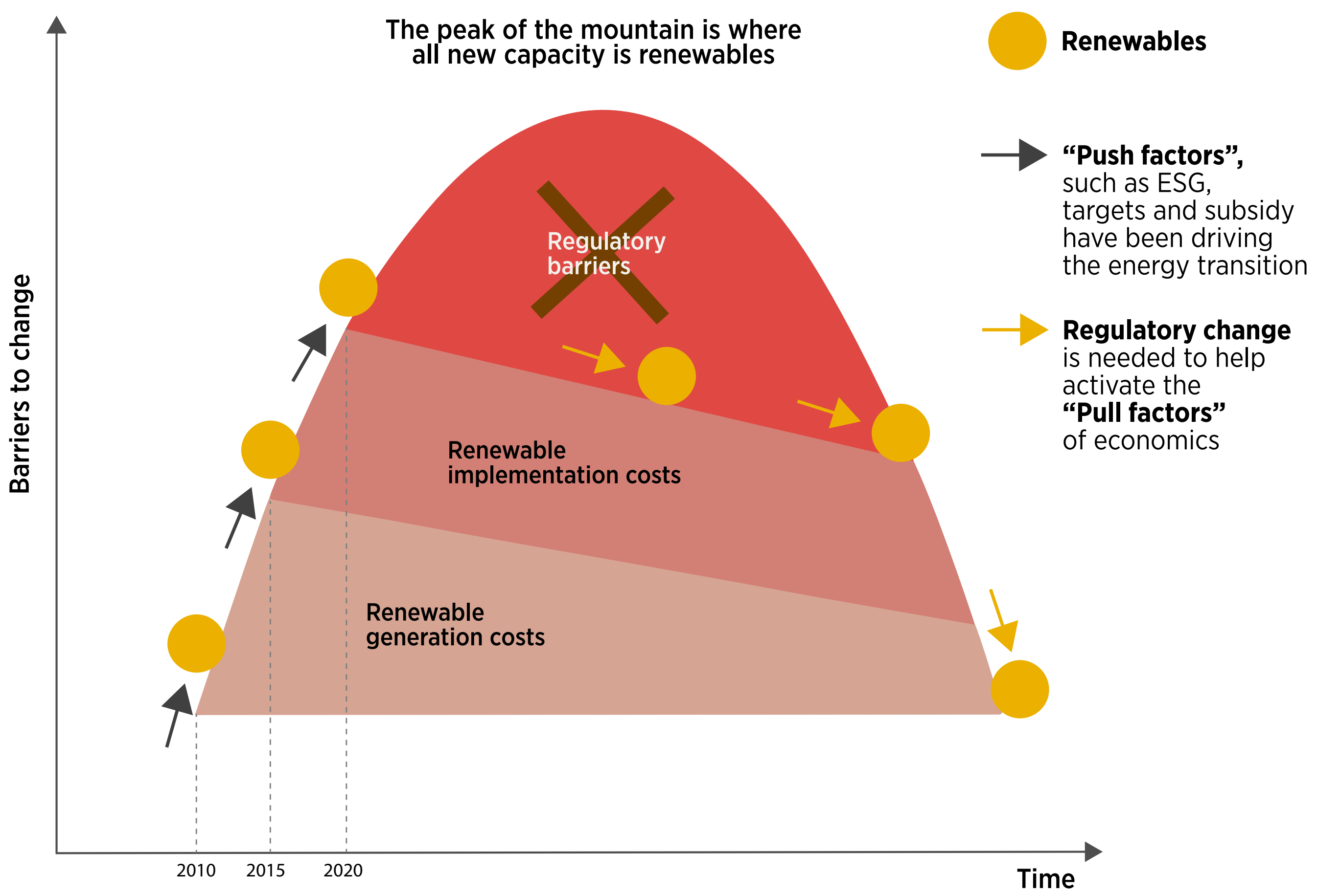
4.3 PUSH FACTORS AND PULL FACTORS

Push factors such as subsidies or environmental, social and governance (ESG) scores are those which move against the grain of economics (Figure 13). Pull factors are those which seek to create an environment in which economics can drive change, such as changing policy codes to allow renewables to compete fairly. The analogy of pushing a ball up a hill illustrates this.

In broad terms, policy makers should be looking to move from push factors to pull factors as the transition progresses and renewables costs fall. And as IRENA notes (2021), at all stages they need to implement enabling regulations to ensure that this is a just transition.

- **Push factors** seek to move the ball up the hill of barriers to change by helping newcomers or cajoling incumbents. They include ideas such as a taxonomy of green investments, green bonds, subsidies for renewables, Paris targets or targets for the share of capital in green finance.
- **Pull factors** seek to remove the regulatory and structural barriers to change and allow the ball to run down the hill thanks to the superior economics. They seek to create conditions under which companies will seek to embrace and profit from change. They include removing subsidies for fossil fuels, amending electricity codes to allow for free competition and making polluters pay.

Figure 13: The push and pull factors of the energy transition



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