2

Energy Transitions

In a scene that could be mistaken for a romantic hideaway in the Caribbean seas, David Wethe (2016) described the spot where oil drillers lie idle. The place is "one of those idyllic spots touched most days by little more than a fisherman chasing blue marlin, billions of dollars worth of the world's finest oil drilling equipment bobs quietly in the water". The place is where Transocean's oilrigs hibernate.[1] The scene, however, is every C-Suite executive's nightmare:

> They are high tech, deep water drill ships—big, hulking things with giant rigs that tower high above the deck. They are packed tight in a cluster, nine of them in all. The engines are off. The 20-ton anchors are down. The crews are gone. For months now, they have been parked here, 12 miles off the coast of Trinidad and Tobago, waiting for the global oil markets to recover. (Wethe 2016)

Across the continental shores of the United States, Tesla is making waves with the launch of the Model S (Heisler 2016). The car is described as a technological breakthrough in mobility. With a price tag of $30,000, Model S ushers the dawn of electric-powered mobility by a car that can go the distance affordably.

Reported over a span of 24 h, Transocean and Tesla are responding to two very different futures. Transocean scans the horizon and can only see valuable assets laid to waste as oil drilling activities dry up with no respite in sight. The next sunrise is hoped to usher in a better day—but hope is about the only thing that keeps managers going. In contrast, Tesla rides a wave of optimism that the

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company is on the cusp of hitting pay dirt. Notwithstanding the managers' optimism, rising losses are about the only outcome Tesla can currently show.

These contrasting responses to changing fortunes are illuminating. As technological shifts disrupt the world that managers come to know, the uncharted waters become uncertain terrain for incumbents. However, for firms that seek to change the world, the risks posed by an uncertain world form the backdrop for seizing opportunities that are hitherto unknown. Steven Sinofsky, formerly of Microsoft Windows,[2] describes this process: "Disruption is a critical element of the evolution of technology—from the positive and negative aspects of disruption a typical pattern emerges, as new technologies come to market and subsequently take hold."

Trapped in their daily rush from one activity to the next, managers seldom fully comprehend how their world is changing. Yesterday's headlines are readily forgotten, as managers focus on the next item on their agenda. While they go about their daily chores, the world continues to move on. Belatedly, as the firm is left behind and hits a crisis, managers have very little recourse but to grin and bear it, and hope for the best. The response? Tinkering on the sidelines passes for innovation, while hope is a substitute for strategic responses. Thus, cost-cutting and delaying commitments are recurrent themes that play out in the boardrooms during downturns or crises of epic proportions alike.

The outcomes are far from satisfactory. Managers seek alternative ways to tackle their predicament, but are caught in the "financial discipline" that defaults into a static world of "business as usual". However, as the march to the future leaves these firms behind, managers who grasp what an alternative could offer may flourish.

As Transocean imagines a world that will continue to demand oil to fuel its energy needs, the lull is a temporary setback. With sufficient financial commitments and resources, Transocean can rebound when drilling activities start to recover. Such a perspective, however, is under threat from the alternative futures that Tesla is committing money to create. In Tesla's world, Model S or its successors will require no fossil fuel. Electrons power these cars, thereby eliminating CO_2 emissions. As power generation decarbonises, Model S may render internal combustion engines obsolete, and with this mark the demise of fossil fuels.

Under these contrasting futures, and the commitments that each adherent is making, the struggle as to which future prevails is no longer a passing fancy that managers can dismiss as yesterday's headlines.

Energy Transitions—Markets, Technologies, and Policy Actions

Energy transitions, and how they are triggered, are analysed across ideological divides with contradictory prescriptions. Examine for instance these two divergent views that are articulated in academe and in policy.

On one side, we have an all-knowing government that employs policy—a pro-interventionist stance—to carefully orchestrate energy transitions. In this world of command and control, bureaucrats are endowed with omniscience in order to foresee and the omnipotence in order to assert society's "best interests"—in whichever way these interests are defined. As their reward, compliant firms gain access to protected niches where revenue can be extracted.

On the other side, we have a market economy where competing forces and interests shape the outcomes. In this messy world, the outcomes evolve rather than being predetermined, supported by a policy stance that is "pro-business". Volatility and uncertainties are part and parcel of this transition. In response, managers shape their actions, tempered by the rules that govern how their markets operate. In this dynamic world, policy arbitrates between conflicting interests while moderating abuse by firms that possess dominant market power. Through dynamic competition, resources are allocated according to the firms' capacity to take risks and innovate in order to gain a viable niche in the market. Risk-taking is rewarded by returns to firms that deliver better or cheaper ways of accessing energy.

Between these opposing systems is a world where managers reside, striving to survive under competitive stress. As politicians of different shades alternate in the seats of power, managers are confronted with a shifting conception of society's "best interests". To prosper, they need to anticipate or respond to swings in markets from conditions that are described vaguely as "pro-business" or "pro-interventionist", to the reverse, and back again. Within this world, geopolitics, economics, and technology transitions coexist, asserting their influence on how energy markets evolve. In the process, the ebbs and flows of policy's primacy, or its irrelevance, have come to form part of managerial strategic decision-making.

Vaclac Smil (2010) describes transitions as "passages from one condition or action to another". Applied to energy transitions, these changes are often manifested in two aspects:

1. *Composition or structure of primary energy supply* where transition involves a "gradual shift from a specific pattern of energy provision to a new state of an energy system";
2. *Change in energy conversion processes* with the "gradual diffusion of new inanimate prime movers, devices that had replaced animal and human muscles by converting primary energy into mechanical power".

The energy transition, however, requires "technical and infrastructural imperatives, and because of numerous social and economic implications, energy transitions are generally protracted affairs". Smil further argued:

> A world without fossil fuel combustion is highly desirable and (to be optimistic) our collective determination, commitment, and persistence could hasten its arrival – but getting there will exact not only a high financial and organisational cost but also persistent dedication and considerable patience. As in the past, the coming energy transitions will unfold across decades, not years – and a few facts are as important for appreciating energy prospects of modern civilisation as is an informed appreciation of this reality.

The element of "persistent dedication and considerable patience" raises a practical question. The answers to this cannot escape by addressing the ideological underpinnings that define the manager and policymaker's world views. Under what system of governance and incentives could these elements thrive?

Technology, and its diffusion, is made possible when a market exist. The policy-reliant approach looks to government to nurture and protect a niche, where the "existence of such niche to pay more" for what the new technology could offer would enable the "new technologies to be refined gradually until they could compete with the incumbent energy source" (Fouquet and Pearson 2012). Hence, to sustain an energy transition, "policies and innovation efforts need to be persistent and continuous, aligned, as well as balanced" (Grubler 2012).

This prescription collides with market realities, and the arena where managers conduct their business. Under democratic systems, the shifting priorities of governments coincide with the electoral process to maximise votes. As the winds of public opinion change direction, what was perceived as sound policy that served society's "best interests" could now be seen as the source of society's ills when a change in regimes occurs. Hence, public opinions hardly form a reliable base to encourage "efforts that are persistent and continuous", much less "aligned and balanced" as Grubler would prescribe.

In contrast, authoritarian regimes are believed by their advocates to provide stability, so that "command and control" policy imperatives can thrive. However, authoritarian regimes are equally in a bind. Endowed with presumptive omniscience to know what there is to know, and omnipotence to do what needs to be done, authoritarian governments often fall into a trap of persisting in failed policies. However, as these policies are ruthlessly pursued without control or public accountability, the interests of the few define what society's "best interests" are. While transient prosperity is feasible, popular discontent can overthrow autocratic regimes, often accompanied by turmoil, when people's (unrealistic) expectations far exceed the government's ability to deliver.

An alternative perspective looks at economic agents acting with autonomy, taking individual decisions and commitments that conform to their notions of good. Good, in this context, broadly incorporates the firm's world view that influences how they balance their economic, social, and societal obligations. Under this market system, the currency of trade transcends monetary gains and the narrow economic interests of firms. They include the currencies of ideas, reputation, and goodwill that interact, and through these interactions the monetary outcomes become the consequence, rather than the primary end that the firm's actions are directed towards. Hence, through this competition of ideas, opportunities are transformed into platforms that can be monetised, while the common good is defined under principles that govern human relations. At its most fundamental level, this is informed by natural law.[3]

For the manager, Bernardo M. Villegas, former member of the Constitutional Commission in the Philippines, provides this guidance:

> A most fundamental principle of natural law is the concept of the common good, which should be defined as a social or juridical order which enables every individual human being, endowed with inalienable rights, to attain his or her fullest or integral development. This definition is in contrast with the erroneous definition of the common good as "the greatest good for the greatest number", which can lead to an erring majority tyrannizing a minority. Hence, as an example, to murder or to defraud is universally accepted as a breach of this universal rule, regardless of what the prevailing public opinion may suggest otherwise.

Under this market economy, energy transitions rely on an array of interests and forces that govern and make markets work. While energy market liberalisation may have led to modest efficiency gains, as Michael Pollitt (2012) argues, it has "significantly improved the governance of monopoly utilities (via independent regulators), and the prospects for competition and innovation". At least for the United Kingdom (UK), the benefits have been more clear cut. Stephen Littlechild (2001), the first regulator to pioneer the competitive wholesale market, attributed the 25–35% price cuts in real terms to the combination of competition in power generation and retail supply, tighter price controls in transmission and distribution, and the elimination of the nuclear levy.

In the messy world where managers reside, energy transition is subjected to ever-changing policy prerogatives, often responding to how technologies and markets reconfigure the energy system. As this reconfiguration unfolds, managers have to deal with the interactions of technology, temporal shifts in economy, and policy actions that conspire to reshape the energy system (Kemp et al. 1998). Under these evolving scenarios, the end game is far from set—with each "milestone" often triggering the next moves from competing interests. To flourish in this ever-changing business landscape, managerial flexibility is at a premium. Managers act and change course as market conditions warrant—often pre-empting competition to shift competitive advantage in their favour.

To make sense of these market dynamics, we examine energy transitions in the context of the three areas that managers can influence—either as the prime movers of change, or reacting to the effects of changes that other players have initiated.

The Big Waves—Technology and Supply Substitutions

Known energy resources are generally of two types. The first is high-density resources, such as fossil fuels, which can be transported and converted affordably and benefit from the economies of scale. Hence, through centralisation, cost advantages are cemented, although emissions of CO_2 pollute the environment. The second is dispersed and freely available in nature: water, steam, wind, and radiation. Collecting and transforming these resources requires significantly higher capital expenditure, although they generally enjoy zero fuel costs. In their converted forms, they produce renewables such as hydro, geothermal, wind, and solar power, with biofuels extracted from vegetation.

Under a fossil fuel-dominated energy system, the market for raw materials (or feedstocks) is centralised to achieve these advantages. Collected at a central point, the fuels can be brought to a central processing facility where primary fuels are converted into energy. In the process, economies of scale reduce the costs of production and logistics, hence erecting barriers to substitution—as illustrated in Fig. 2.1.

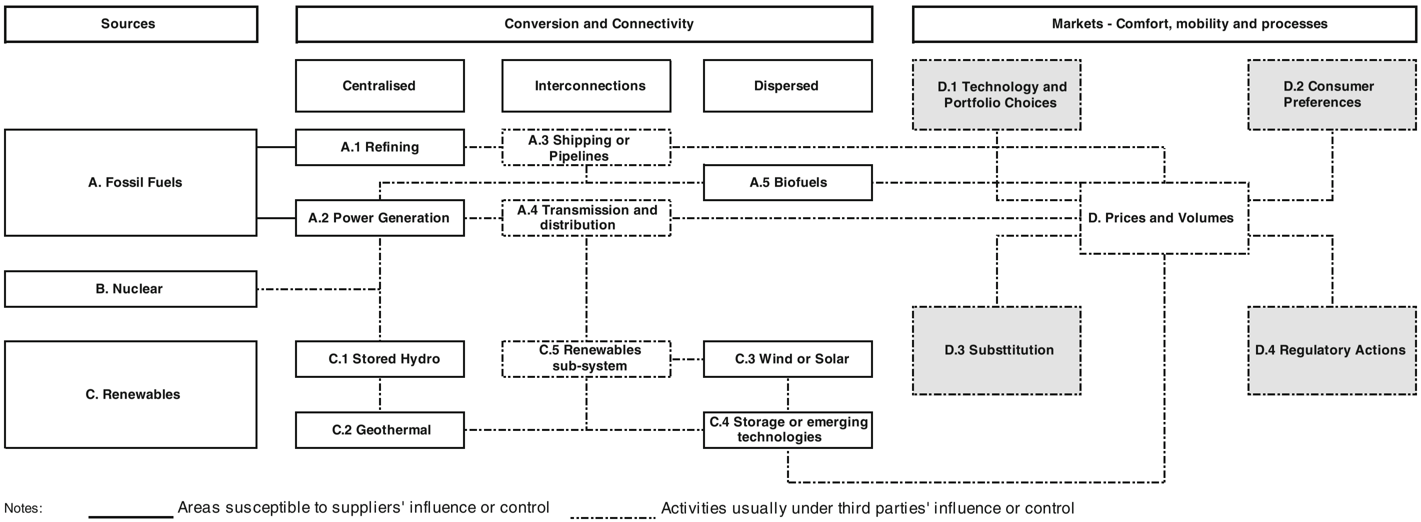

Fig. 2.1 Markets, technology, and system reconfiguration. *Source* Adapted from author's works at King's College London

Fossil fuels (A) in the forms of oil or gas are shipped (A.3) to refineries (A.1), and transported as energy (or fuels) (A.3) that consumers can readily use for transport (mobility), household use (comfort), or to produce goods and services (processes). The market for energy offers suppliers periodic volumes or prices (D), as the mechanism for converting supplies into revenues and the payoffs. Under this centralised energy system, the control over resources such as fossil fuels (A), access to logistics (A.1 and A.3), and the capacity to influence prices and volumes (D) (usually as oligopolistic supplier) define the market power of the firm.

Power generation (A.3) works in a similar way, although fossil fuels (A) (i.e. coal, oil, or gas) could be substituted with nuclear (B) (i.e. uranium), which power generators (A.2) convert into electricity (or power). The power is transported through the transmission lines or distribution system (A.4) to consumers' premises. Under liberalised power markets, the system is unbundled so that power generation, transmission, distribution, and commercialisation are separate activities, often undertaken by different firms. Through the wholesale power market, competing suppliers trade electricity, with buyers bidding for supplies where periodic prices and volumes are set. As with fossil fuels, the energy market defines the revenues and payoffs of suppliers through the mechanisms of prices and volumes.

Emerging technologies may substitute incumbents with their gradual integration into capital-intensive logistics in order to access energy markets. Alternatively, new technologies may initiate a reconfiguration of how consumers access their energy supplies, which could force incumbents to adapt at high costs or ultimately make them obsolete (see Box 2.1).

Box 2.1: Uniper and the New Eon Have Contrasting Business Profiles

Eon and RWE sought radical restructuring as their strategic response to Germany's *Energiewende*. The move proved costly to the German energy industry, capped by a new $26.3 billion levy to cover the cost of storing nuclear waste.

Eon opted to split into Uniper, where the nuclear, hydro, and fossil fuel assets were held, and Eon, to own offshore and onshore wind assets, together with the regulated business.[4] However, the government forced Eon to keep its nuclear assets, worried that Eon may dodge its share of the nuclear levy. Guido Hoymann, analyst at Metzler Bank, noted: "It means that both Eon and Uniper have negative momentum, which will burden their valuations."

RWE opted for a simpler spinoff, where a new subsidiary was created to hold its renewables, grid, and retail operations, with plans for a 10% share offering in 2016.

In describing the breakup of his company, Eon chief executive Johannes Teyssen said he wanted to give investors "optionality".

Those who believed electricity prices and the value of commodities such as coal, gas, and carbon will recover could invest in Uniper. Those who wanted to own a regulated business with "resilient income streams, irrespective of volatility of commodities", could opt for Eon, he said.

"We will not grow endlessly—it's not like in the commodities business," he added. "But we will have resilience and predictability. Our capabilities will decide things, not fortune and the markets."

His logic is compelling. Shares in European energy companies with heavily regulated businesses, such as Terna, which operates Italy's transmission grid, and Snam, which runs its gas pipelines, have performed much better since the financial crisis than so-called integrated utilities such as Eon.

The changes are inevitable, said Hans Bunting, head of RWE renewables. Political interventions have played havoc with energy markets over the past few years. In response, utilities have concluded, Bunting says, that: "We'd rather concentrate on those markets where the government already intervenes but in a more predictable manner. And those are in our view the regulated markets."

Adapted and quoted from Guy Chazan, Financial Times, 18 May 2016.

The emergence of renewables creates two deployment pathways. First, we have stored hydro (StoHydro) (C.1) and geothermal (Geo) (C.2), energy sources that are renewable where supplies are amenable to being modulated according to demand. Given these characteristics, they are readily integrated into mainstream power systems. Second, we have dispersed renewable sources such as wind (Wind) (C.3) or solar (PV solar) (C.4), where supplies are intermittent. In a number of systems, these renewables are subsidised and given preferential despatch whenever they are available. Spain has one of the few systems where renewables are consolidated under a subsystem, with unified despatch to the wholesale market. The advantage of this approach is to minimise the intermittent supply of dispersed renewables, their volatilities being managed in a similar way to StoHydro.[5]

Dispersed renewables (C.3 and C.4) could be embedded as decentralised supplies. As such, they can bypass power transmission and distribution systems and directly supply customers. This is where dispersed renewables, as they increase their scale, could disrupt the mainstream power system. Such disruptions occur at the following levels:

1. *Barriers to entry are lowered while economies of scale are redefined* when dispersed power supplies are directly connected to consumers or consumers themselves become suppliers, as in the case of roof-top solar power panels.

2. *Price erosion* becomes a feature in the continuing financial viability of extant and new power supplies.
3. *Smart grids potentially substitute* rigid networks to accommodate the dynamic despatch that increased renewables deployment implies, while turning customers into suppliers (when solar panels sell excess power to the grid) and giving consumers greater control over their volumes.

These disruptive influences directly impact prices and volumes (D), where renewables (C.1–C.3) could substitute for fossil fuel-based supplies (A) or nuclear power (B). The interaction of prices and volumes (D) is in turn influenced by the technology and portfolio decisions (D.1) that potentially alter the supplies mix. Hence, as more renewables become available and compete on economic criteria, their zero fuel costs provide a physical hedge against volatile fuel prices. For this reason, at certain fuel prices, renewables are the cheaper supplies by virtue of their low variable costs. For suppliers with a diverse technology mix, their despatch strategy would follow portfolio optimality rather than maximising individual asset payoffs.[6] As a result, substitution (D.3) of fossil fuels (A) with renewables (C.1–C.3) follows iterative and dynamic processes, where technology choices (D.1) feed into the consumption of specific types of fuels.

To empirically examine this phenomenon, we illustrate the effects of the change in supply mix on periodic power prices. We draw on our work on the Spanish system, given the spread of technologies that interact in the wholesale power market. In Fig. 2.2, we illustrate how the change in the proportion of fossil fuels in power supplies could translate into a variation in power prices. That is, as fossil fuel-based supplies increase, this implies that the more expensive assets are despatched. Hence, the marginal costs of supplies would increase, translating into higher periodic power prices (or vice versa). Similar results are shown in other systems with mixed technologies, such as the Nordpool (Botterud and Korpås 2007), and our analysis of the wholesale market of England and Wales.

Charts A and B show that monthly and quarterly changes in power prices are positively correlated with the changes in the share of fossil fuel-based supplies respectively. Charts C and D show the power prices, and how they fluctuate periodically, from 2001 to 2016. That power prices are volatile is a known and accepted reality among energy managers. However, how the addition of renewables changes the accepted wisdom (that any new capacity is price neutral) is now open to question.

The implications for investment valuation are significant, and influence whether or not to commit. Let us examine these two contrasting approaches—NPVs or option-games reasoning—and the kind of decisions that they are likely to support.

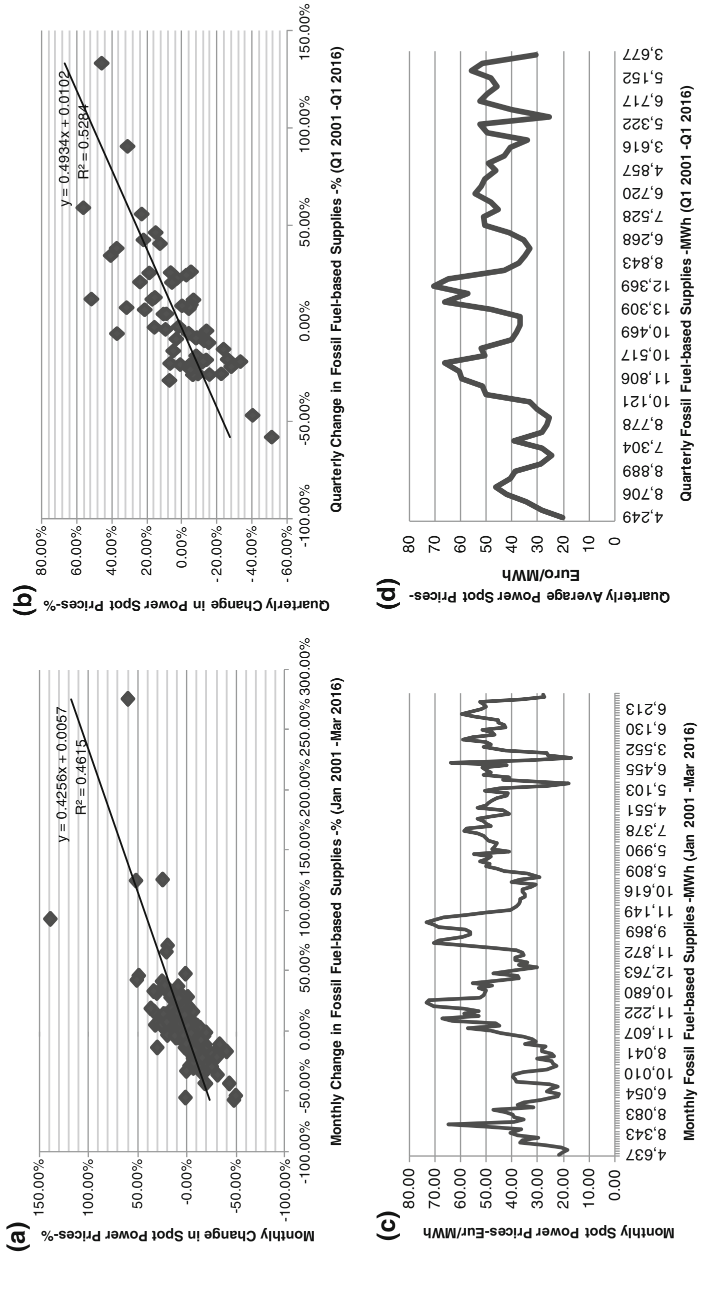

Fig. 2.2 Spain—power price and fuel mix variations. *Source* Adapted from author's works at King's College London, using raw data from Spain's OMEL

Energy managers who learned their financial analysis using net present values (NPVs) tend to evaluate their investments as a single commitment, where predictable cash flows are valued highly. Once an investment is made, managers implicitly assume that the commitment is a "now or never" decision. For this reason, when market conditions change, as they often do, managers explain this adverse change as a deviation from budget. The causes are attributed to market forces outside their control. However, when price increases flatter the outcomes, managers are not shy to credit the outperformance to the prowess of their timely actions. There is of course some truth to these claims. However, what is implicit in this reasoning is more important. Once a commitment is made, NPVs leave the outcomes to the vagaries of the markets. Given that any prior commitments are sunk, the sunk costs do not feature in any forward-looking decisions. As a default, proven technologies are favoured with optimisation biased towards individual asset performance, while ignoring their portfolio effects.

A manager schooled in option-games logic would focus on the degree of managerial flexibility that allows the appropriation of the values of embedded options and the avoidance of losses.[7] These options are the *call* on future payoffs when power prices are higher or a *put* option on future fuel costs liabilities. Seen in this perspective, the value of renewables is framed as a hedge against fuel price volatilities, given their zero fuel costs. Hence, the commitment cost (or capital expenditure) is the price paid to gain access to the option values, among which is access to zero fuel costs for long-term power supplies. Following this reasoning, prior commitments are recognised as the firm's initial endowment, which could limit or expand their strategic options. Going back to Fig. 2.2, the technology choices are radically altered, as follows:

1. *Price erosion from renewables* implies a potential for declining asset values for fossil fuel-based supplies when lower than expected power prices prevail as the "new normal".
2. *Hedge value of renewables* partly offsets the effects of price erosion from extant fossil fuel-based supplies when the firm decides to expand with renewables instead of coal or gas, with potentially eroding values.
3. *Loss avoidance* is feasible when firms can interrupt supplies when there is managerial flexibility in cases where supplying would incur a loss. Conversely, the ability to ramp up volumes when prices are high (or cash margins widen) could increase payoffs.

Taking a view on the competitive landscape, managers can decide on their technology choices being informed by how their competitors' actions could impact the firm's portfolio value. Under this dynamic decision-making, diversifying into renewables may prove the optimal decision, albeit counter-intuitive under NPV's logic.

Temporal Shifts: Income–Energy Consumption Nexus Revisited

Intuitively, the influence of income on energy consumption appears obvious. Logic suggests that as income rises, consumers can afford more appliances that consume more energy. As markets increase the level of electrification, and energy becomes more accessible, convenience shifts demand to more power-intensive goods and services. In the case of mobility, the affordability of private vehicles further strengthens the correlation between income and energy consumption. A similar evolution occurs when industrialising the manufacturing process adds impetus to the economy's energy intensity.

Figure 2.3 plots the evolution of fuel usage over very long historic patterns. Starting with the era of horses and carriages, the three basic functions of energy have hardly changed: providing comfort, mobility, and fuelling processes. What has changed is the mechanisation of work, where human and animal labour has been replaced by what Smil (2010) refers to as inanimate prime movers (or machines).

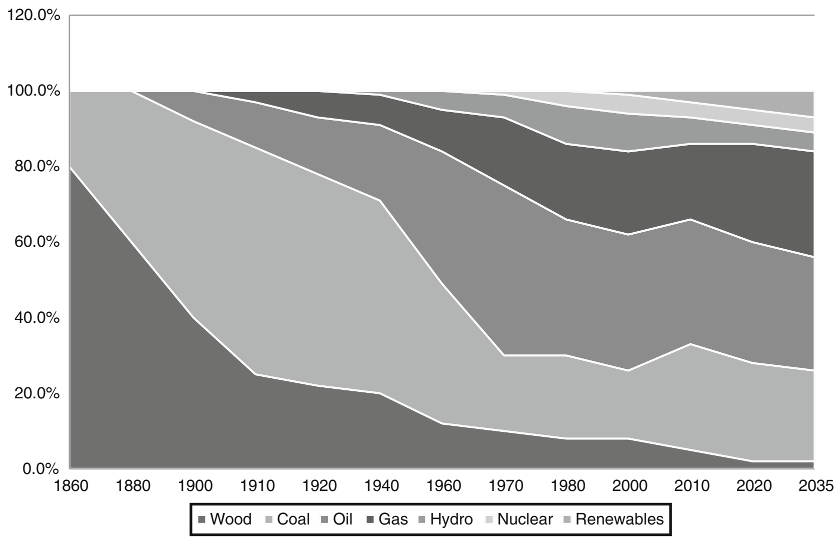

Fig. 2.3 Fuel use transitions. *Source* Adapted from BP and Shell, with forecasts from EIA and BCG

The first transition occurred during the nineteenth century when steam engines emerged as the dominant technology. Coal was the preferred fuel, given its higher calorific value, hence its gradual replacement of biomass or wood as the main fuel source. The emergence of motorised vehicles at the turn of the twentieth century saw internal combustion engines replacing steam engines as the dominant technology for mobility.

With this technological shift, oil as the preferred fuel was substituted for coal because of the following factors:

1. Oil was more convenient to transport and use, compared to the bulkiness of coal.
2. Electrification made energy available to households and industry for the first time "at a click". The combination of affordability and convenience is a powerful impetus for substitution.
3. As the cost of oil became more competitive, the shift in its favour became decisive after the Second World War, when reconstruction and industrialisation boosted energy consumption.

Golub and Townsend (1977) provided insights into the 1960s US refinery capacity glut, showing how prolonged under-investment meant that the Arab oil embargo, when it was implemented, had an inordinate impact. With oil prices at historic lows, oil refiners and exporting countries suffered from losses. In response, oil-exporting countries formed the Oil Producing and Exporting Countries (OPEC) group, to control output and buoy prices. Meanwhile, the 1968 US Supreme Court ruling against petrol price increases deterred major investment in refineries, domestic exploration, and production; and this tightened domestic supply. Thus, while the 1973 oil crisis was seen as politically motivated, weak investments that responded to signals about poor prospects exacerbated US vulnerability to the oil boycott. Golub and Townsend further argued that as an offshoot of these events, second tier multinational companies, with governments too weak to champion their causes and feeling vulnerable to concerted international actions, banded together to launch the Club of Rome.

The 1973 oil shock placed supply security at the forefront of energy policy. This is where the pathway to the next fuel transition saw a divide between nuclear and gas. In searching for a response to the Arab oil embargo, countries opted to diversify their fuel sources. While mobility and processes remained heavily reliant on oil, power generation was more successful in weaning itself away. Increasingly, power generation saw the emergence of gas, with power generators adopting combined cycle gas turbines (CCGTs) in the 1990s. In

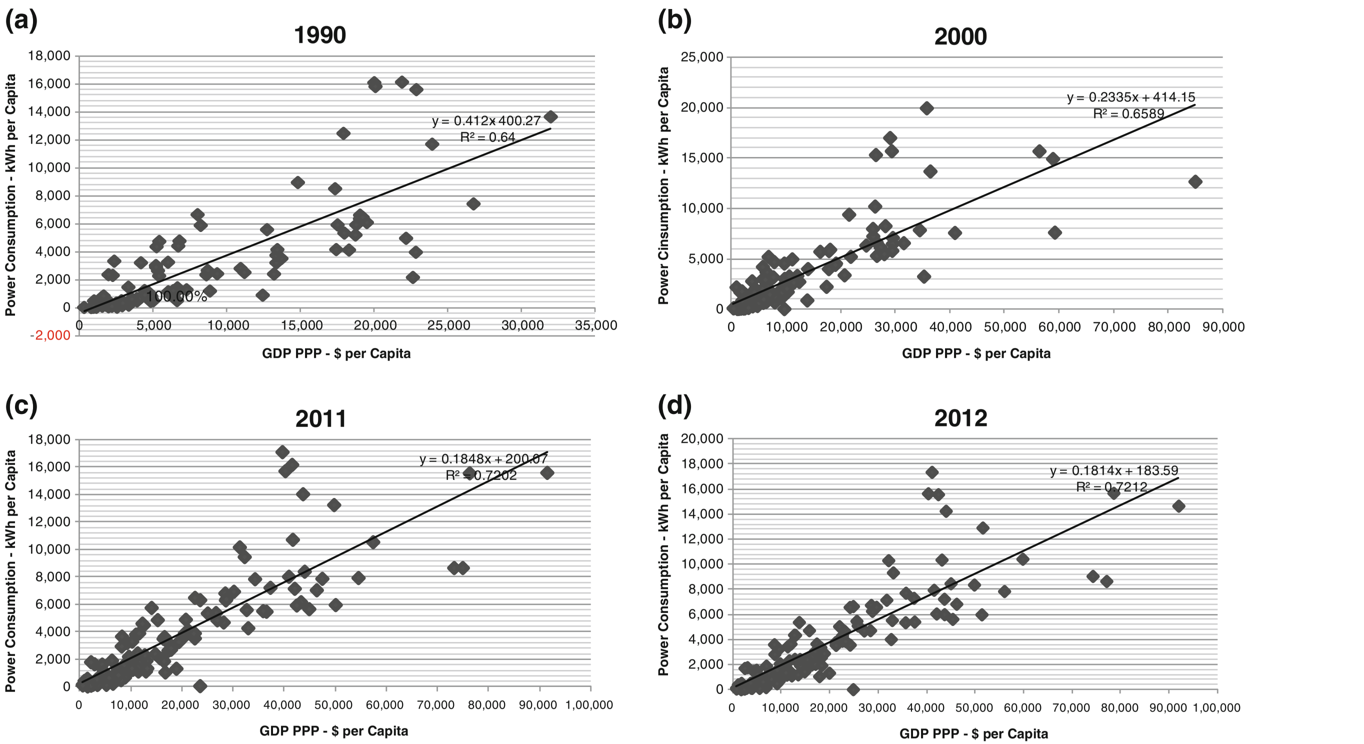

Fig. 2.4 Income and per capita power consumption. *Source* Adapted from author's works at Barcino Advisers, Hong Kong, with raw data from World Bank Database

contrast, France, Belgium, and a number of other countries opted for nuclear during the 1970s, and most started commercial operations during the 1980s.

Having seen how technology choices are made, it is notable that societal choices are somehow locked into a narrow range of alternatives once these choices gain traction. Hence, there is the question about how consumption growth is correlated with rising income, the default choice of fuels often favouring the prevailing dominant source of energy. Thus, as we note in the subsequent discussions, fossil fuels and the power intensity of the economy are the dominant themes when we plot the trajectory of economic growth and energy consumption.

Income and economic development fuel power consumption when they are positively correlated, as we illustrate in Fig. 2.4. Our analysis took a cross-section global sample of 104–124 countries,[8] according to the years when complete data are available. Since 1990 (A), the influence of income on power consumption has been declining, as indicated by the lower values of β and α in our regression analysis. We offer these economic observations:

1. Considered as a power consumption function, α relates to autonomous consumption regardless of income level, while β is the influence of income on the amount of power consumed per capita.
2. In 1990 (A), global consumers needed 400 kWh of power as their autonomous power consumption, while each dollar of income added 0.41 kWh to power consumption.
3. By 2012 (D), the respective values for α and β declined to 183 kWh and 0.18 kWh respectively.

The declining power intensity of the global economy is attributed to rising efficiency, where less power is needed for each unit of income. A similar phenomenon is observed for fuels, which are measured in kg of oil equivalents in Fig. 2.5. Following a similar analysis to power consumption, globally energy consumers would have an autonomous fuel consumption of 340 kg in 1990 (A), where each dollar of income would add 0.21 kg of oil per capita. These values declined to 269 and 0.099 kg of oil equivalent per capita by 2012 (D). One may say that the world in general has become more energy efficient since the 1973 oil shock.

The world, however, is far from forming a homogeneous energy market that exhibits similar energy intensity and income elasticity. The level and pace of energy consumption is driven by economic development, where emerging markets tend to grow faster than developed economies as the former "energise" their economy. Income effects experience threshold limits, where beyond such income levels the influence of income on power and energy

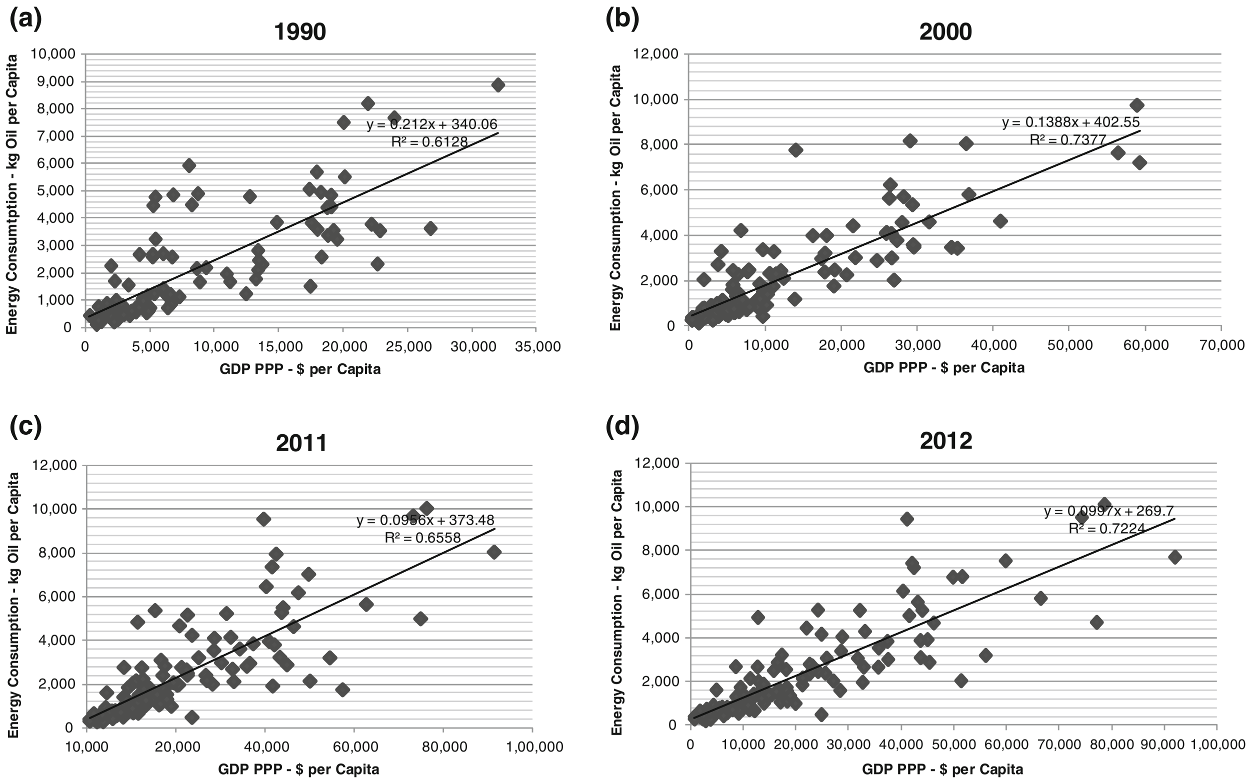

Fig. 2.5 Income and per capita energy consumption. *Source* Adapted from Barcino Advisers, Hong Kong, with raw data from World Bank Database

consumption weakens. In a selection of European and Asian markets, we attribute this phenomenon to a process of dematerialisation in the economy: see Fig. 2.6.

Asian markets such as Malaysia, China, and Indonesia are generally on a growth path, where rapidly rising incomes are translated into increasing power and energy consumption. Indonesia's slower growth, while consistent with the country's lower incomes, is partly hampered by poor logistics and weak infrastructure. Hence, without access to energy sources, isolated areas are shut out of the energy market—whether or not consumers have the income to afford to consume more energy or power. In a study of six developing countries, Sari and Soytas (2007) argued that energy is an essential factor of production, heavily reliant on fossil fuel and power. To develop their economies, and hence to raise income, access to energy is a stronger impetus than the abundance of labour or capital (Sari and Soytas 2007).

The high-income European countries are in a phase when per capita consumption of energy is declining more rapidly, while power consumption is stabilising and showing early signs of decline. The dichotomy in the patterns of consumption is explained by the following factors:

1. Decarbonisation of European power systems has seen a shift from oil and coal to gas, while nuclear and hydro are dominant sources of power supplies in specific markets such as Scandinavia, France, and Belgium.
2. European markets have been undergoing a process of dematerialisation, which most developed economies are experiencing, where a reduction in resource use per unit of gross domestic product (GDP) occurs as an economy passes certain income thresholds—a phenomenon observed in the more advanced Asian markets (Galli 1998).
3. "Electrification" of industrial and work processes displaces fossil fuels as direct energy inputs. Hence, while energy per capita consumption declines, power consumption remains stable as a result of this substitution.

Environmental advocates see the rising incomes in emerging markets as posing a strain on global energy supply. They extrapolate the patterns of growth in developed economies, and somehow assume that similar levels of energy would be needed to fuel similar levels of economic development.

However, recalling our energy system reconfiguration in Fig. 2.1, power prices impact the level of energy volumes (D), where substitutions (D.3) and consumer preferences (D.2) play significant roles. This is where the asymmetric impact of rising income on energy consumption finds a viable explanation. In countries with high power and energy prices, economic development is biased towards energy-efficient or less energy-intensive

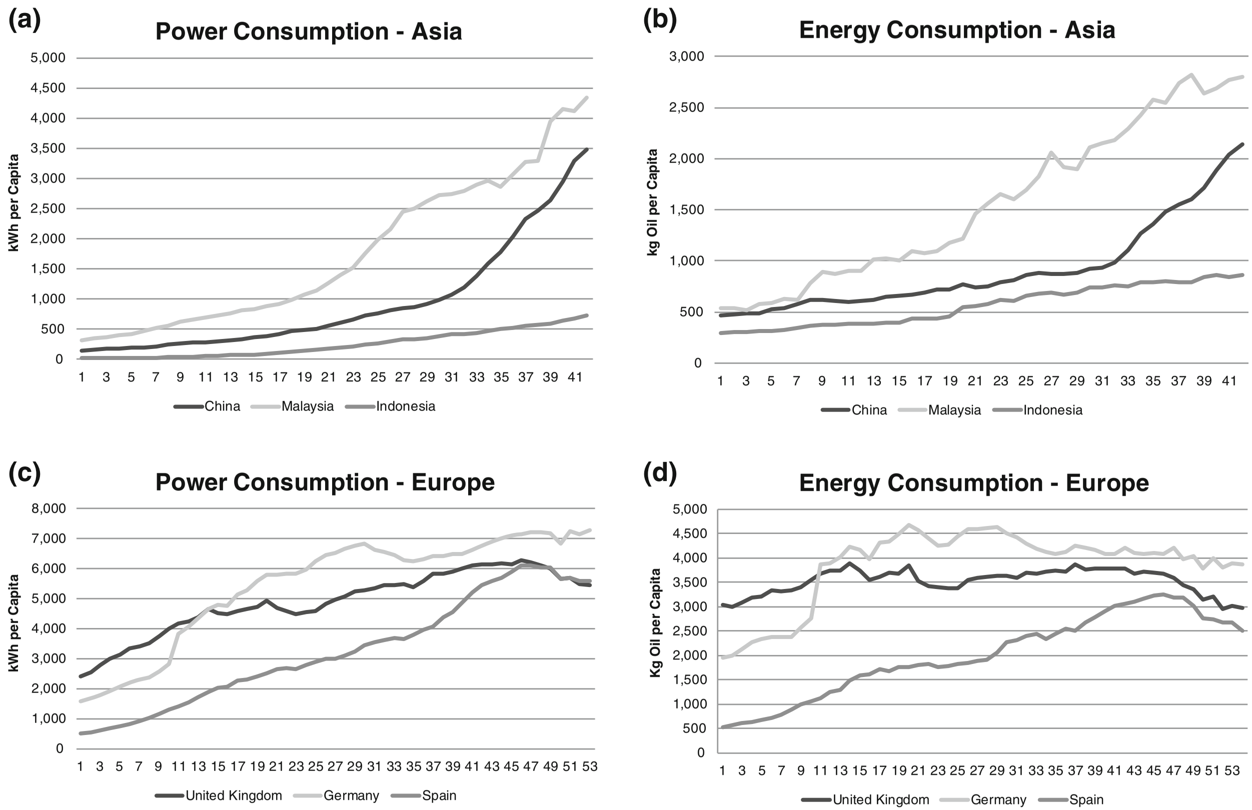

Fig. 2.6 Process of dematerialisation of economy. *Source* Adpated from Barcino Advisers, Hong Kong, with raw data from World Bank Database

industries. This stands to reason, given that competing markets with lower prices, *ceteris paribus*, would gain in manufacturing where energy costs account for a significant proportion of production costs (or vice versa). In the process, deindustrialisation occurs at much lower levels of income than previously experienced in industrialised economies (Ravago et al. 2016).

The radical shift in the future, however, is likely to come from breakthrough technologies in electrical mobility. We should recall Tesla's Model S as an example, where a broader diffusion of electrification in mobility may render fossil fuel consumption forecasts in Fig. 2.3 far too optimistic. Imagine a world where mobility—land, marine, air, and space—has decarbonised to a similar extent as power generation in Western Europe. The share of fossil fuels would be less significant than today's forecasts are suggesting.

But then, a revival of internal combustion engines is feasible if oil and gas prices remain lower for longer—prolonging the period of coexistence between fossil-fuel vehicles, hybrid vehicles, and electric vehicles. Over this extended coexistence, a hybrid system of multiple fuels is more likely to prevail. In the end, what consumers decide may tilt the balance one way or the other.

Policy Actions and Energy Transitions

Policy responds to some perceived threats, such as a supply shortage, where actions are couched under a supply security mantra, or public preferences for less polluting energy. While the prominence of the "green agenda" appears a recent development in energy policy, it dates back to an earlier epoch.

Contrary to the neo-Malthusian view, scarcity plays minimal role in energy transitions. What Lewis (2008) refers to as "natural resources false alarms" is best captured when quoting Stanley Jevons's *The Coal Question* of 1865, an academic treatise. Jevons argued that British industrial pre-eminence was doomed to decline, given that coal could only be mined at ever greater depths and that spiralling costs would "cripple industries dependent on it". Jevons boldly declared that "it is useless to think of substituting any other kinds of fuel for coal".

Since 1865, British industrial pre-eminence, while eclipsed by the United States, remains in company of prosperous nations. As Fig. 2.3 illustrates, coal ceded its predominance to technology and fuels that did not exist in 1865, hardly because the world was running out of coal. Notwithstanding this historic reality, Jevons's intellectual descendants continue to sway the policy process. Examine, for instance, the following:

1. *1914 forecasts of peak oil* by the United States Bureau of Mines suggested that American oil would last no more than a decade;
2. *1972 Club of Rome report on Limits of Growth* (Meadows et al. 1972) predicted that the entire global oil reserve of 550 billion barrels could be used up within a decade. By 1990, consumption reached 600 billion while reserves stood at 900 billion, thanks to new discoveries, better extraction technologies, and investment.
3. *Beyond the Limits* (Pestel 1989), trying to rectify the errors of *Limits of Growth*, predicted that oil would run out by 2031 and gas by 2050. Instead, fractured oil and gas turned the United States from a net importer to a net surplus producer.

The work by UN IPCC on climate change,[9] suggesting impending doom if no immediate action was taken, raised the stakes for policy inaction. The recommendations are encapsulated in the *Stern Review* (2006), which Nordhaus (2007), Henderson (2008), Lewis (2008), Byatt (2008), and Barry et al. (2008) challenge. The climate debate recalls earlier prescriptions on "social discount rates" (Hasset and Metcalf 1993, 1999; Jaffe and Stavins 1994) that follow the NPV logic. By applying low discount rates, these proponents suggest that the value of renewables is raised so as to enable them to compete for capital with fossil fuels-based supplies. Far from being a twenty-first-century novelty, few energy transition dynamics departed from their historical patterns—as suggested by Table 2.1.

The confluence of technology and a case for collective action are elements that propel policy actions, where external shocks act as catalysts for accelerated transitions. Specifically:

1. *Coal use reduction in the UK (1860s–1960s)*. London was notorious for its dense and foul-smelling fog, and "smog" was a recognised problem from 1948. Attempts to lobby for government action began when the National Smoke Abatement Society was formed. It was not until after 4,000 people died in 1952 from smog that the government passed the Clean Air Act, in 1956. Coal emissions were banned in London and most urban areas, resulting in the demise of coal as a primary heating fuel.
2. *Nuclear power as panacea to 1973 oil shock (1980s–2000s)*. Supply security amidst geopolitical realignments led a number of governments to embrace nuclear as the panacea, being "too cheap to meter". France, Spain, the UK, Sweden and the United States, among others, embarked on massive capacity building alongside coal-fired plants to wean themselves from oil dependency. With the exception of Brazil's alcogas programme, most

Table 2.1 Technology transitions and fuel usage

Period	Dominant technologies	Dominant fuel	Policy triggers	Switch in fuel use
1860s–1960s	Steam engines	Coal	Clean air act London fog	Oil
1920s–1970s	Internal combustion engines Stored hydro power Nuclear power	Oil	Oil Shock—1974/1975 Reduce oil dependency Fuel conservation	Hydro and uranium Gas as emerging fuel
1980s–1990s	Combined cycle gas turbines Hybrid cars Nuclear power	Oil/Gas	CO_2 emissions control Power market liberalisation	Gas as transition fuel Renewables Uranium
1980s–2000s	Advance combined cycle gas turbines Wind power Decentralised energy systems	Oil/Gas	Decarbonise energy systems Going green	Multiple fuels Local fuels
2000s–?	Renewables Power storage Low carbon fossil fuels or substitutes Waste recycling or recovered fuels	Hybrid/multiple fuels	Waste management Research and development support "*Energiewinde*"	Multiple fuels Power storage as emerging technology Renewables

Source Adapted from Barcino Advisers, Hong Kong; BP; Shell Scenarios transport-related initiatives during this period that focused on biofuels and electric/hybrid cars fizzled out as oil prices fell.

3. *Harrisburg (USA) and Chernobyl (Russia) nuclear disasters (1980s–2000s).* While not directly linked to the transition to gas, the pre-eminence of natural gas as a preferred fuel proceeded in parallel with nuclear. Nuclear moratorium allowed CCGTs a space to develop while bringing capital costs down from $1,500/kW in the 1970s to $450/kW in the 1980s from higher adoption rates. Thus, when power markets were liberalised in many countries in the 1990s, CCGTs went on to dominate power generation, with ACCGTs as upgrades, given low gas prices.

Spain started out as heavily reliant on hydropower, with coal and oil not becoming a feature until well into the 1960s. The Franco era policy of autarky relied on indigenous energy resources, hydropower and coal, given the regime's political and economic isolation (Navarro 2008). Spain's re-entry into international markets in the latter part of the 1960s led to developing imported coal and oil as complements to hydropower.

Taking their guidance from policy, where capacity expansion was centrally planned, Spanish power utilities traded compliance in exchange for secure returns to deliver the state's preferred capacity mix. Thus, in the aftermath of the 1973 oil shock, nuclear and coal were central to Spain's strategy for achieving self-sufficiency. As a private "contractor" to the state, consumers via the tariffs assumed risks associated with volatile demand, costs, and technology obsolescence. Not surprisingly, Spain persisted with having among the most expensive electricity prices prior to the 1990s market liberalisation.

Post-liberalisation, the basis on which power and gas markets were organised changed. Wholesale markets, an independent regulator, integration with unbundled businesses, and utilities competing for market share resulted in a divergence in returns. As a consequence, managerial flexibility and differences in strategic responses reshaped the industry, which saw mergers and relative differentiations in capacity mix and strategic positioning.

As state-owned entities, investments in capacity in the UK were influenced by an obligation to supply power securely, while ensuring jobs for coal miners. A defence programme with nuclear capabilities influenced technology choices, which explains the divergence from the European nuclear capacity strategy. The Central Electricity Generating Board (CEGB) reluctantly adopted the advanced gas cooled reactor (AGR). While defence planners chose AGRs, CEGB preferred the pressurised water reactors (PWR) that were opted for by France and most European utilities (Holmes 1992).

Post-privatisation, the UK pioneered competition in Europe through the wholesale power and gas markets. With incentives for efficiency, and accountability to shareholders, privatised power generators shifted their primary focus from investments to optimising returns, rather than supplying security and job creation. Perhaps for this reason, investments became skewed to CCGTs and eventually to ACCGTs, at the expense of nuclear and coal, given its triple advantages of relatively lower capital outlays, fuel costs, and emissions.

As de facto contractors to the state, Spanish and UK utilities optimised returns through compliance with state objectives, while offloading risks to consumers, in exchange for stable and predictable returns sufficient to recover costs and remunerate assets. In contrast, competitive markets required utilities to operate under greater uncertainty, where returns performance diverged according to differences in capabilities, technological choices, and risk taking. Thus, while state-regulated systems tended to yield lower variability in returns, competitive markets produced diverse financial fortunes, as risk-taking and rewards were internalised.

On closer examination, European energy policy was pursued largely to meet a broader conception of best interests for society, with energy security a collateral reward. For example, the French nuclear programme was aimed at promoting and sustaining heavy engineering and technological excellence (WNA 2016). The British opted for coal, to utilise their sizeable coal reserves and assure the continued viability of coal mines as a way of securing employment. Privatisation and market liberalisation resulted in the accidental growth of gas—resulting in an unplanned transition from oil to gas with the emergence of CCGTs (Littlechild 2001).

While France succeeded in expanding its power industry, heavily dependent on nuclear, national champions in heavy engineering did not fare as well. As the massive nuclear build-up came to an end, they did not achieve the global leadership that they aspired to. In fact, Alstom had to be rescued with a $3.4 billion equity injection, loans, and guarantees to customers by the French government (Carregrow 2003). Within a year, Finance Minister Nicolas Sarkozy was staving off Alstom's bankruptcy by letting state-owned nuclear power firm Areva take over Alstom's power plant business (*The Economist* 2004). Fast forward a decade, and it was Areva's turn to be bailed out.

Optimistically, Areva's Chief Executive Philippe Knoche told investors in a conference call that Areva would be an attractive company. Growth in the nuclear industry and the closure of old power plants would increase demand for both nuclear fuel and for nuclear waste handling (Landauro 2016). As investors scanned the horizon, as Transocean's managers did in the Caribbean seas, they came to realise that not too many customers were making a beeline to Areva's door. Meanwhile, Areva's bonds traded at 88% to a Euro and fell shortly thereafter to a 22% discount, with banks and bondholders sharing in the pain that the French government had failed to stave off (McCrum 2016).

While France and Belgium succeeded in shifting from oil to nuclear after 1974, the transition to gas for the UK and Spain was a slower process. France's success hinged on the realisation that the country's substantial heavy engineering expertise was the cornerstone of the shift to nuclear (WNA 2016). With few known energy resources, France opted for nuclear technology, because it relies on engineering excellence and fuel accounts for a small part of power generation costs.

In contrast, the "dash for gas" did not gather pace until the 1990s when the UK saw the confluence of four factors: (a) cheap gas was available; (b) lifting of a ban on burning gas for power generation; (c) stronger environmental regulations (i.e. a shift from coal to gas) and competition (i.e. cost-competitive gas replacing coal); and (d) the higher efficiency and upscaling of combined cycle gas turbines (CCGTs), making the technology a viable substitute for coal-fired plants (Kern 2012). Spain followed, with major power generators such as Endesa, Iberdrola, Gas Natural, and Union Fenosa jumping onto the gas bandwagon towards the latter part of the 1990s.

Renewables have proven less resilient financially, particularly those that are heavily subsidised such as wind or solar power, where global deployment rates fall far short of policy objectives. By 2015, while wind and solar "represents about half of gross capacity additions from 2009 to 2015, their total share of capacity remains modest at 6.7% and 2.0%, while accounting for 4.7% and 0.9% of production respectively" (EIA 2016).

The twenty-first century ushered in the "age of the environment", and with it low carbon aspirations. The "dash for gas" in the 1990s that appeared to cure oil addiction is now a cause for concern. At the height of the debate about the UK's energy bill in 2012, politicians greeted with a chorus of concern the prospect of increasing CCGTs and ACCGTs from 8 GW in 2011 to 31 GW in 2030. Tim Yeo, Conservative and chair of the energy and climate change select committee, sounded this alarm: "The idea that unabated use of gas is a long-term solution is mistaken." He added: "There is a significant risk in being very dependent on gas in the 2020s because the world price may be much higher than it is now." Caroline Flint, Labour shadow energy secretary, concurred with this warning: "There is a real risk the government's dash for gas will blow a hole through our climate change targets, undermine investment in clean energy and leave households vulnerable to price shocks and rising energy bills" (*Observer* 2012). France is not spared from the wave of "green energy". In 2014, the Green Growth bill was passed, mandating a 50% cap on nuclear power, implying the closure of 1,650 GW of nuclear capacity by 2016. Carbon tax is the other plank, where a progressive application would see taxes increase from \$24.86/tonne CO_2 in 2016 to \$113/tonne CO_2 by 2030 (WNA 2016).

Germany embarked on the most ambitious programme for decarbonising an energy system through *Energiewende*. This programme seeks to reduce energy consumption by half by 2050 through energy efficiency, while shifting supplies from coal and nuclear to a system with 60% renewables. The objectives are to create green jobs to compensate for job losses in coal and nuclear, reduce risks of nuclear accidents through progressive shutdowns of nuclear plants, and reduce CO_2 emissions (Morris and Pehnt 2016).

The initial enthusiasm of the German government turned to caution, when the cabinet decided to limit renewables capacity additions in the north as transmission line expansion lagged. By aligning the pace of capacity additions, supplies from the north could be connected to the highly industrialised markets of the south (Fuchs 2016). The impact to incumbents, by any reckoning, poses existential threats (see Box 2.1).

Krzysztof Tchórzewski, Polish Minister of Energy, encapsulates the broader challenges that confront policy and managers as follows:

> The uncertainty concerning the future of energy policy in the European Union and falling power prices, together with an increase in costs of its production, result with investments in conventional energy sources becoming economically unviable. As a result, we are dealing with ever increasing burdens that stem from the development of renewables that are being placed on the citizens. These burdens are included in the energy prices. These circumstances force European energy professionals and policymakers to seek innovative solutions to the problems both of producing and financing the sources of energy and heat.

Concluding Thoughts and Reflections

Energy transitions are triggered by a confluence of factors. As energy technology changes, the impact on fuel use depends on the pace of adoption and substitutions. Such pace is in turn driven by economics and competition, while policy actions may hasten or impede the speed of transition. As technologies gain traction, temporal shifts in economic growth and income tend to favour expansion in consumption of the preferred fuels.

As society locks itself into certain technologies, the infrastructures and the systems for providing energy become embedded in how comfort, mobility, and processes are met. Renewables have to surmount these barriers, involving a protracted process of integration, complementation, or substitutions that could disrupt energy systems as we know them. As Smil (2010) argued, this energy transition would "exact not only a high financial and organisational cost but also require persistent dedication and considerable patience".

Given this reality, policy-induced transitions may inflict enormous pain on incumbents, as the German *Energiewende* is exacting its toll on the German energy industry. With a determined move towards a renewable future, flourishing firms such as Eon and RWE have found themselves struggling to survive the existential threat unleashed by the government.

A market economy, in contrast, offers managers the prospect that firms can create their own market niches and formulate their strategic responses. As technological shifts disrupt the world that managers have come to know, the uncharted waters become uncertain terrain for incumbents. However, for firms that seek to change the world, the risks posed by an uncertain world form the backdrop for seizing opportunities that have hitherto been unknown.

To the triumphant, they may reap rewards for their risk-taking, while forever changing the shape of the global energy system. For those that flounder, they may have taught the world, at great costs to themselves, what does and does not work, and why. After this, the brave may make another plunge—perhaps the wiser resulting from this learning process.

Notes

1. Transocean is reputed to be the largest offshore rig operator.
2. Sinofsky was President of Microsoft's Windows Division. He is credited for creating Outlook.com, Internet Explorer, and SkyDrive, among other systems.
3. Natural law is a set of human values and rights with which our human nature is endowed based on the immutable laws that govern nature. Through this understanding of the nature of the person and society, a set of binding rules governing moral behaviour can be arrived at and adhered to.
4. Eon's 2015 pro forma earnings before interest, tax, depreciation, and amortisation (EBITDA) was \$5.98 billion, while Uniper's was \$1.92 billion, reflecting how it was hit hard by lower power prices, which have fallen from \$67.8/MWh in 2011 to \$28.3/MWh, and declining volumes, as coal and gas were squeezed out by heavily subsidised wind and solar power. The amounts are converted at \$1.13 for every Euro.
5. Chapter 9 explores this topic in greater depth.
6. Chapters 5 and 6 compare how the portfolio approach differs from single asset optimality, and discuss the influence on technology choices.

7. Chapters 7 and 8 discuss the applications of option games to evaluating energy investments under oligopoly and dynamic markets.
8. The breakup of the former Soviet Union and the Balkan states accounted for most of the increase in sample size.
9. Inter-governmental Panel for Climate Change is an agency of the United Nations.

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