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A Changing Competitive Landscape: Transition Policy's Blind Spots

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For the past two to three decades, and particularly in the wake of the Great Recession, clean energy transitions have been sold as a three-for-the-price-of-one policy: creating "green collar" jobs to get the unemployed back to work, using domestic resources to reduce dependence on imported fossil fuels, and all while reducing carbon emissions. The first of two implicit goals of this "three-fer" was the development of local, high tech industries supported by policy-driven domestic demand for wind and solar equipment. These high tech industries would, in turn, deliver the second goal of driving down the costs of clean energy technologies to the point where they would no longer require policy support.

The effectiveness of transition policy in meeting these goals can be measured by relative improvements along two dimensions:

- Cost competitiveness of the new technology versus the incumbent fuel and technology combinations within a country; and
- Cost competitiveness of domestic clean tech manufacturing and service industries versus global suppliers.

For the most part, intentionally or not, policy and incentive design seems to have overlooked the evolution of competitive pressures in these two dimensions. There appear to be three blind-spots:

- Policy support may create demand that outstrips the local supply chains' ability to expand – thus generating the high tech "green jobs" overseas. For example Germany's solar photovoltaic industry was unable to match the surge in domestic demand precipitated by aggressive policy support, and Germany was forced to resort to imports, mostly from China.
- Policy support may underestimate the pace at which costs of a new technology are falling, due to innovation or otherwise, and remain inadvertently over generous. The resulting uptake frenzy can only be calmed by removing or reducing the incentive. Spain, Germany, and the United Kingdom, among others, provide such examples.
- Policy support may underestimate the pace of innovation in the incumbent fuel and technology combination and, ultimately, the consequences of moving down the supply cost curve if demand for the incumbent declines. This has the effect of necessitating more support, for longer than anticipated or withdrawal of support before the new technology is sustainably cost competitive. Wind energy in the United States shows how technology progress and supply chain expansion within the incumbent natural gas fired fleet can overwhelm wind power cost reductions even before demand for natural gas fired generation begins to decline.

These examples suggest that policymakers and relevant stakeholders may benefit from incorporating more realistic representations of likely changes in the competitive dynamics of industry and trade into their energy transition planning. This is particularly important in the longer term if the penetration of clean energy capacity results in a reduction in the absolute demand for fossil fuels. This will elicit an even more competitive response from suppliers of those commodities and in related value chains than has been seen to date. Not only will demand clear further down the supply cost curves but the curves themselves will likely begin moving downwards as suppliers apply their innovations.

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Introduction

Whether through feed-in-tariffs (FIT), renewable portfolio standards (RPS), power purchase agreements (PPA), investment tax credits (ITC), or otherwise, there are three broad goals that drive governments to require a shift in reliance on fossil fuels to renewables:

- achieving greater energy security and/or independence,
- mitigating negative environmental impacts, and
- developing manufacturing and service sectors that would contribute to economic prosperity and create employment opportunities.

Each of these goals poses challenges on its own. If two or more goals are to be achieved simultaneously, the task becomes even more complicated because these transition goals may compete with each other.

During the past 25 years particularly, many countries around the world have set targets that are to be met in a specified timeframe. For example:

- Australia committed that at least 20% of its electricity needs will be met from renewable energy by 2020 (Moosavian *et al.*, 2013).
- Germany has gone beyond just an electricity generation target and intends to reach a renewables-based share of gross final energy consumption of 18% by 2020 (BMU, 2012).
- Saudi Arabia plans to increase its generation capacity to nearly 120GW by 2032, and 41GW of which will be provided by solar energy (KACARE, 2014).

As can be seen, the targets can be represented as a percentage of electricity generation, a percentage of energy consumption, an absolute number, or a combination of these.

While the percentage share of incumbent fuels and technologies has somewhat shrunk through time, their absolute consumption level has not (Fouquet & Pearson, 2012). Policies supporting renewables and/or penalizing conventional energy sources are intended, ultimately, to decrease the demand for conventional energy. If the latter occurs, the demand for conventional energy would down the supply cost curve to the low production cost regions, making conventional energy attractive. By the same token, as demand for renewable technologies increases, their selling prices would be set further up the supply cost curve, making them less attractive.

Global energy demand has not been stagnant – it has been steadily increasing with an exception during the Great Recession. Global oil consumption for example has grown more than 10 million barrels per day above 2003's level of over 80 million barrels per day according to the 2014 BP Statistical Review. This increasing demand has drawn increasingly expensive resources into the supply cost curve and caused markets to clear at higher prices than would have been the case in an environment of stagnant demand. Similar growth has occurred in demand for gas and coal. This growth in demand for conventional fossil fuels can thus be viewed as having contributed to the competitiveness of renewables.

As a general rule of thumb, history tells us that transitions require prolonged periods of time to evolve (Grubler, 2012). The prevailing economic, social, technological, and socioeconomic conditions, among others, will impact the design of policy to varying degrees. The displacement of conventional electricity generation requires the development of a new technology that is *competitive* with the incumbent. Financial policy instruments aim to incentivize investments in renewables and subsequently improve the economics of renewable generation. Energy transition policy has also typically been seen as offering encouragement to the development of the local renewable technology service and manufacturing sectors. In support of such economic growth objectives, direct and indirect incentives are utilized to establish globally-competitive national supply chains. Considering local and global competitive dynamics is, therefore, central to transition policy design. Locally, ambitious penetration targets mean, at least partially, winning the competition for power generation. Globally, the race among nations to establish market leadership can have significant implications on national industry formation and expansion.

Identifying Blind Spots in the Policy Process

Policy makers typically recognize the likelihood of improving performance of renewable technologies in the future and how the costs of manufacturing the components may change over time with the aid of learning curves (Reichelstein & Yorston, 2013) and scale economies (Yu *et al*., 2011). Both factors are particularly important if a government intends to adopt push policies. But energy transitions are too complex to be described or characterized by a few theories or equations, and it is reasonable to assume that deviations from what was expected may (and indeed, will) occur. In fact, entirely unexpected developments may arise and require consideration in policy formation. The catastrophe that occurred in Fukushima in 2011, for example, is one that frustrated several plans and warranted full reevaluation of (renewable) energy policies and targets. Such developments are not ones that could be anticipated.

The effectiveness of transition policy can, by and large, be measured by assessing improvements in relative competitiveness along two dimensions: (1) cost competitiveness of the new technology versus the incumbent fuel and technology combination within a country; and (2) cost competitiveness of domestic manufacturing and service industries versus global suppliers. Intentionally or not, policy and incentive design seem, for the most part, to have overlooked the evolution of new competitive pressures in these two dimensions. This paper will identify and discuss three resulting blind-spots:

- Policy support may create demand that outstrips the local supply chains' ability to expand – thus generating the high tech "green jobs" overseas. An illustration is provided by Germany's solar photovoltaic (PV) industry being unable to match the surge in demand precipitated by its aggressive support of PV technologies. This forced German customers to resort to imports, mostly from China.
- Policy support may underestimate the pace of innovation in a new technology and remain inadvertently over generous, precipitating an uptake frenzy that has to be calmed by removing or reducing the incentive. Spain, Germany and the United Kingdom, among others, provide such examples.
- Policy support may underestimate the pace of innovation in the incumbent fuel and technology combination and, ultimately, the consequences of moving down the supply cost curve if demand for the incumbent declines. This has the effect of necessitating more support for longer than anticipated or withdrawal of support before the new technology is sustainably cost competitive. For example, wind energy in the United States demonstrates how technological advancements and supply chain expansion within the incumbent natural gas fired fleet dwarfed cost reductions in the wind sector even before demand for natural gas fired generation begins to decline.

These examples suggest that policymakers and relevant stakeholders may benefit from incorporating more realistic representations of likely changes in the competitive dynamics of industry and trade alongside market equilibria into their energy transition planning. Note that whether these changes occur as a deliberate competitive response or evolve naturally is immaterial. Such considerations that account for potential changes in the competitive landscape are important in the longer term if the penetration of clean energy capacity begins to reduce the market for fossil fuels in absolute terms. This will elicit a more aggressive competitive response from suppliers of those commodities and in related value chains than has been seen to date (Stenzel & Frenzel, 2008). This competitive response would result from demand clearing further down the supply cost curve and the curve itself moving downwards through continued innovation.

Blind Spot 1: Demand outstripping local industry capacity

Germany's PV FIT program

The Germany PV journey continues to be among the most researched case studies in the field of renewable energy transitions. The intention here is not to elaborate on Germany's progress toward meeting its policy objectives. Rather, we make observations related to the effectiveness of policy instruments in establishing a competitive solar PV manufacturing sector given global dynamics.

The driving force in promoting renewable energy in Germany has been the Renewable Energy Sources Act introduced in 2000, which, based on the German equivalent, is abbreviated as EEG. A FIT program, however, had already been in effect since the early 1990s. EEG set targets for renewable energy, aspiring for other positive impacts including stimulating the economy (Frondel *et al*., 2010) and increasing employment opportunities (Frondel et al., 2008). Given the generous incentive support, it is not surprising to see that Germany has lead the world in cumulative installations of solar PV capacity with approximately 35.7 GW added between 2000 and 2013 (BSW-Solar, 2014). Italy, which is next in line, lags far behind with a total capacity installation of approximately 17.6 GW, nearly half the installations in Germany (IEA, 2014).

The lucrative incentives maintained PV demand at high and stable levels, which was initially somewhat matched by growth in local solar cell production capacity as depicted in Figure 1. However, in 2004 annual PV system installations began growing at a much faster rate than the production capacity.

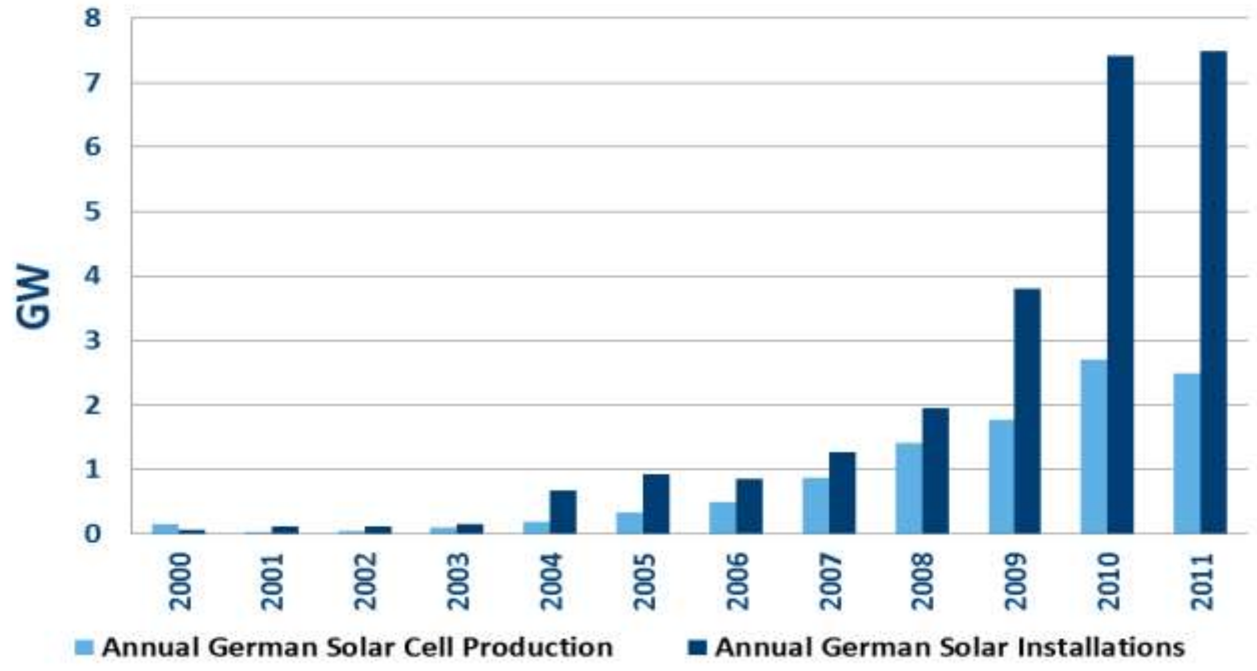

Figure 1: The annual solar cell production and total solar installations for Germany for the years 2000 through 2011. (Source: KAPSARC based on data from Frondel et al., 2008, Hoppmann et al., 2014, and IEA, 2013).

In fact, the annual installations in 2010 and 2011 for example were nearly thrice the local production capacity. Clearly, the national industry was unable to cater for this explosion in demand or grow at a matching pace; Germany began relying more and more on imports to satisfy its demand growth.

Meanwhile, and since the 1990s, China began to provide strong support to export-oriented industries. By the mid-2000s, the share of exports of the gross domestic product (GDP) grew to 36% compared to only 9% in 1980 (Liu and Goldstein, 2013). This focus on exports was also coupled with the desire of the Chinese government to support the development of industries that are both capital- and technology-intensive, and at the same time considered vital for national security and economic infrastructure (Liu and Goldstein, 2013; Mattlin, 2009). The solar PV industry, including silicon purification, wafer manufacturing, and cell production, has easily satisfied these conditions for receiving support.

Multiple policy initiatives have equipped China to become a world leader in solar manufacturing. For example, the ministry of finance (MOF) granted exemption from value added tax and import tax for manufacturing equipment purchase. The ministry of science and technology (MOST), on the other hand, established several national programs to support high-tech research and development. Even city governments played an important role by refunding 50% of the loan interests for investments beyond ¥500 million in solar PV manufacturing equipment and other technologies (Huo & Zhang, 2012). Policy instruments motivated a large surge in solar cell production capacity in a short period of time. In 2011, for example, while Germany produced nearly 2.5 GW of solar cells, China produced nearly 10 times as much. China was able to boost its production from almost 1.5 GW in 2007 to a formidable 26.5 GW by 2012 as shown in Figure 2. Policy support for the PV industry in China, coupled with policy support for solar PV installations in

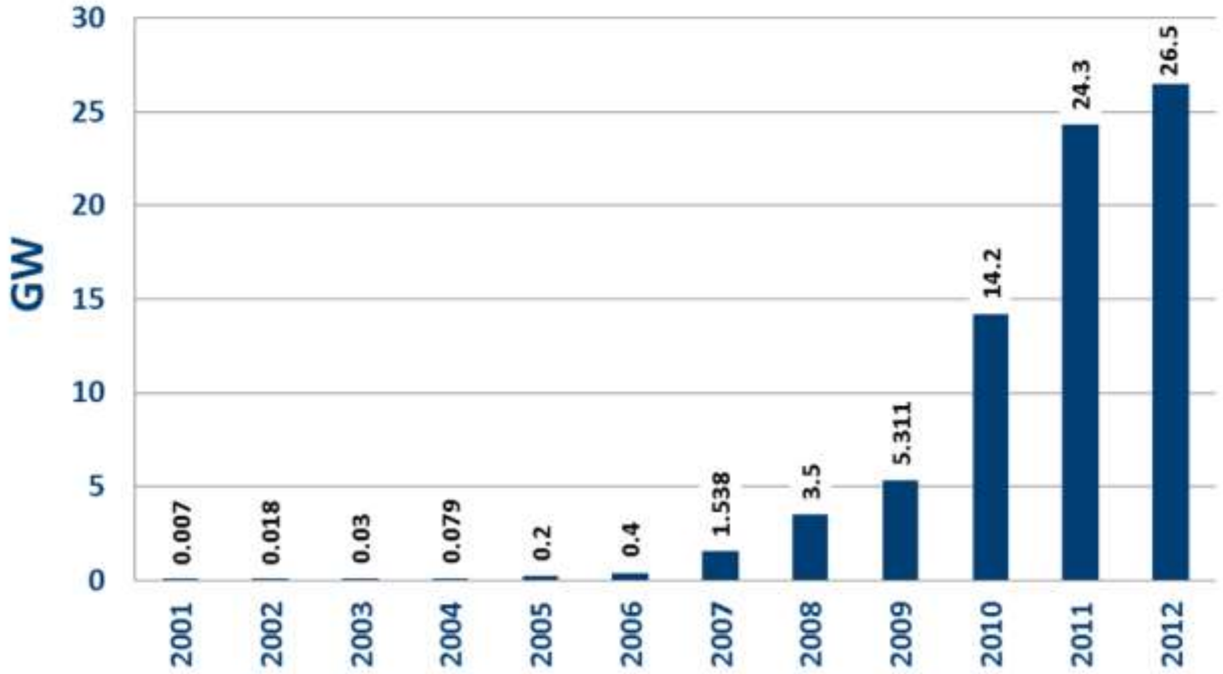

Figure 2: Annual solar cell production for China, including Taiwan for the years 2001 through 2012. (Source: KAPSARC based on Earth Policy Institute, 2014; Fang *et al*., 2013).

many countries worldwide, has made China the major player in the global PV market.

The PV manufacturing sector in Germany was unable to cater for the surging domestic needs or beat China on cost. The latter holds true even if the Germans had not exported any of their PV production; imports covered the deficit, and Germany was a net importer of solar cells for over a decade. Figure 3 shows how net imports increased drastically in 2009-2011, with a growing share of these imports sourced from China.

The Chinese industry has been serving solar PV markets in Germany as well as other countries. At the same time, dissatisfaction has grown in Germany around a wasted opportunity to create jobs and expand the PV manufacturing sector. The competitive position of German manufacturers was further hurt by China, given that the latter was able to produce modules cheaper given unprecedented levels of scale economies (Goodrich *et al.*, 2013). While Germany has succeeded in establishing global leadership in solar PV demand, China has been able to establish leadership in module supply.

When the FIT program was initiated in the early 1990s and then followed by the EEG in 2000, the potential for intensifying global competitive pressures was not clear. It was difficult, and perhaps even impossible, to anticipate that China would evolve into the PV manufacturing colossus it has become. The resultant pressure of manufacturers in China or elsewhere on Germany's PV industry was probably not incorporated into policymaking.

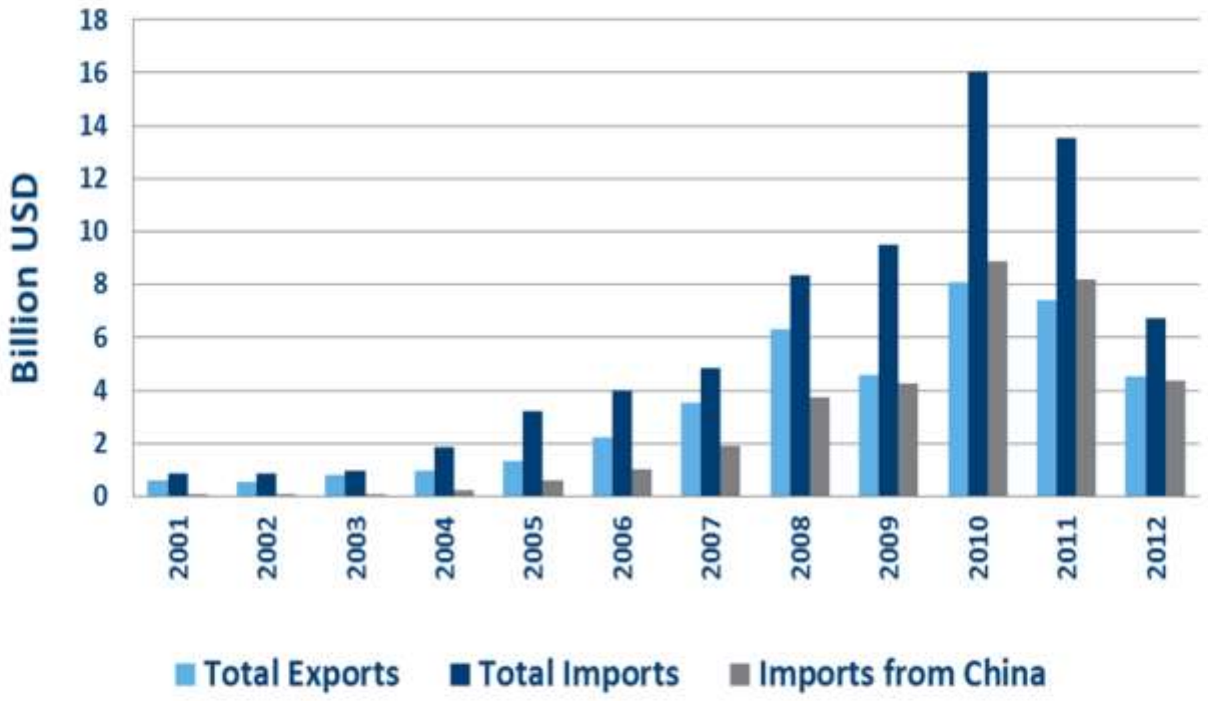

Figure 3: Germany's total exports, total imports, and imports specifically from China of photosensitive semiconductor device, photovoltaic cells & light emit diodes, i.e. harmonized source code: 854140 (Source: KAPSARC based on UN Comtrade Database).

Blind Spot 2: Reasonable incentives becoming profligate

Changes in clean energy technology costs

We continue capitalizing on the German PV experience, since a foundation was built in the previous section, to illustrate how changes in the costs of the renewable technology being supported can result in transforming an existing reasonable policy to an over-generous (profligate) one.

As mentioned, although the EEG came into effect in 2000, it was not until 2004 that the annual installations began to tickle the 1GW mark (Figure 1). The total installations that occurred between 2004 and 2008 were orders of magnitude higher than those that occurred between 2000 and 2004. This explosion in installations however, was also associated with the electricity consumers bearing the brunt; consumers had to carry a heavy 2 billion euros on their shoulders in 2008, which is a 600% increase compared to the 2004 level (Hoppmann *et al.*, 2014).

The situation was further exacerbated as the costs of PV module manufacturing decreased at a faster rate than was expected. Engineering advancements and scale economies were chiefly behind these reductions. Not surprisingly, this cost reduction resulted in an amendment to the EEG in 2009 to mainly limit any additional costs on consumers who have already suffered enough and to curtail manufacturers' windfall profits. Most notably, the static FIT decrease of 5% was replaced by a dynamic reduction mechanism.

But the story does not end there. By the end of 2009, PV systems costs witnessed yet another reduction mainly due to a large drop in silicon spot prices and a global supply-demand imbalance (Bazilian *et al.*, 2013). Once again, the EEG was amended and a reduction in remuneration on all systems sizes was enforced in August 2010; other reductions and amendments have also taken place within this timeframe to the extent that made some academics describe this policy making behavior as compulsive (Hoppmann *et al*, 2014).

The German FIT initially guaranteed a price for PV-generated power that is fixed for 20 years. Although the initial FIT amount may have been relatively, and justifiably, high when it was first implemented to attract investors, it was due to unexpected technological advancements and market dynamics causing global polysilicon supply-demand imbalances that obligated the German government to revisit their previously approved policies.

Blind Spot 3: Competitive advances in the incumbent –

20 years after the US wind production tax credit (PTC)

Numerous federal and state mandatory and non-mandatory policy measures have been put in place to promote a rapid penetration of wind and other renewable energy sources over the past two decades in the United States. Chief among these tools is the federal PTC, which would reward the production and sale of electricity from qualified facilities during the first 10 fiscal years of operation. The PTC was originally introduced by the Energy Policy Act (EPAct) of 1992. Among its objectives was to increase renewable energy production and utilization, advance renewable technologies, and increase exports of renewable energy technologies and related services. Since its first expiration in 1999, the PTC was renewed eight times through 2013 (Table 1).

Also during the past two decades, 29 states and the District of Columbia have enacted RPS policy mandating specific percentages of energy requirements be supplied by renewable energy within specific timeframes (Table 1).

While state RPS has been a key determinant of new facility location, PTC levels and schedules dictated the timing and amount of investments (Figure 4). Between 1993 and 2013, developers added about 60 GW of wind capacity across the United States. However, as suggested by trends in 2012 and 2013, the financial viability of wind plants still appears to hinge upon the availability of federal incentives.

Following innovation and development efforts in the 1980s, new efficient General Electric (GE) “F” class natural gas turbine technology was commercialized in the early 1990s. In addition to its relatively high efficiency, this new technology enjoyed short construction cycles and low capital costs. These advantages, together with restructuring power markets, favorable natural gas price, and supply expectations fueled a gas-fired construction boom between the late 1990s and mid-2000s. About four fifths of power plant installations since the initial implementation of the PTC were natural gas fired. Efficient combined cycle (CC) technologies represents two thirds of this amount as shown in Figure 4.

During the same time frame, electricity demand growth slowed down significantly from an average annual growth rate of about 4% in the 1970s and 1980s to approximately 2% in the 1990s and 1% in the 2000s; this has been driven by a combination of three major recessions, the ensuing restructuring away from manufacturing, and improved efficiencies across the economy. The combination of the power plant building boom and depressed load growth resulted in a capacity glut, and has intensified

Year	PTC Status	States Enacting RPS Policy	States Facing RPS Compliance Deadlines
1990			IA
1992	Introduced by the EPAct of 1992		
1997		NV	
1998		CT	
1999	Renewed by the Ticket to Work & Work Incentives Improvement Act of 1999	ME, NJ, TX, WI	
2001		HI	
2002	Renewed by the Job Creation and Worker Assistance Act of 2002	CA, MA	
2003			MA
2004	Renewed by the Working Families Tax Relief Act of 2004	CO, MD, NY, PA, RI	
2005	Renewed by the EPAct of 2005	DC, DE, MT	NV
2006	Renewed by the Tax Relief and Health Care Act of 2006	AZ, WA	AZ, MD
2007		IL, MN, NC, NH, NM, OR	CO, DC, DE, PA, RI, TX
2008	Renewed by the Emergency Economic Stabilization Act of 2008	MI, MO, OH	ME, MT, NJ
2009	Renewed by the American Recovery & Reinvestment Act of 2009	KS, WV	IL, NH, OH
2010			CA, CT, HI, MN
2011			KS, NM, OR
2012	Renewed by the American Taxpayer Relief of 2012		MI, NC, WA, WI
2013			MO
2014	Expired		

Table 1: Primary federal and state policy instruments supporting wind energy penetration in the US (Source: KAPSARC, using data from multiple state and federal sources).

competition among generating technologies beyond expectations when the PTC was conceived.

More recently, innovation and expansion in production technology further enhanced the competitiveness of gas-fired CC plants. Four decades of innovation in horizontal drilling and hydraulic fracturing (fracking) availed abundant and cheap unconventional natural gas resources (Figure 5). These efforts leveraged initial government support but later benefited from substantial private investment in both technology innovation and supply chain expansion. The subsequent decline in natural gas prices further improved the competitiveness of the efficient, relatively new gas-fired generation fleet. Therefore, the energy transition story that has been making headlines in recent years is that of generation switching from coal to natural gas rather than fossil to wind or other renewable technologies.

The profound shifts in the power market over the last two decades were not anticipated when PTC and RPS rules were conceived. Two decades after the initiation of the PTC, the contribution of wind to the energy mix of the US reached 4% while the share of fossil-fired generation remained roughly the same at 67%. Overall energy requirements rose by one third indicating that natural gas was relied upon to support demand growth, replace retired facilities, and displace generation from older less-efficient fossil-based technologies (Figure 6). The fierce competition among fossil-fueled technologies made ambitious wind energy penetration targets much harder to achieve than originally perceived in the EPAct of 1992. It may be near impossible for state and federal policymakers to exactly predict how advancements in incumbent fuel extraction and subsequent power generation, if any, may evolve. Still, incorporating potential tightening competitive dynamics could be useful for avoiding the cliff-

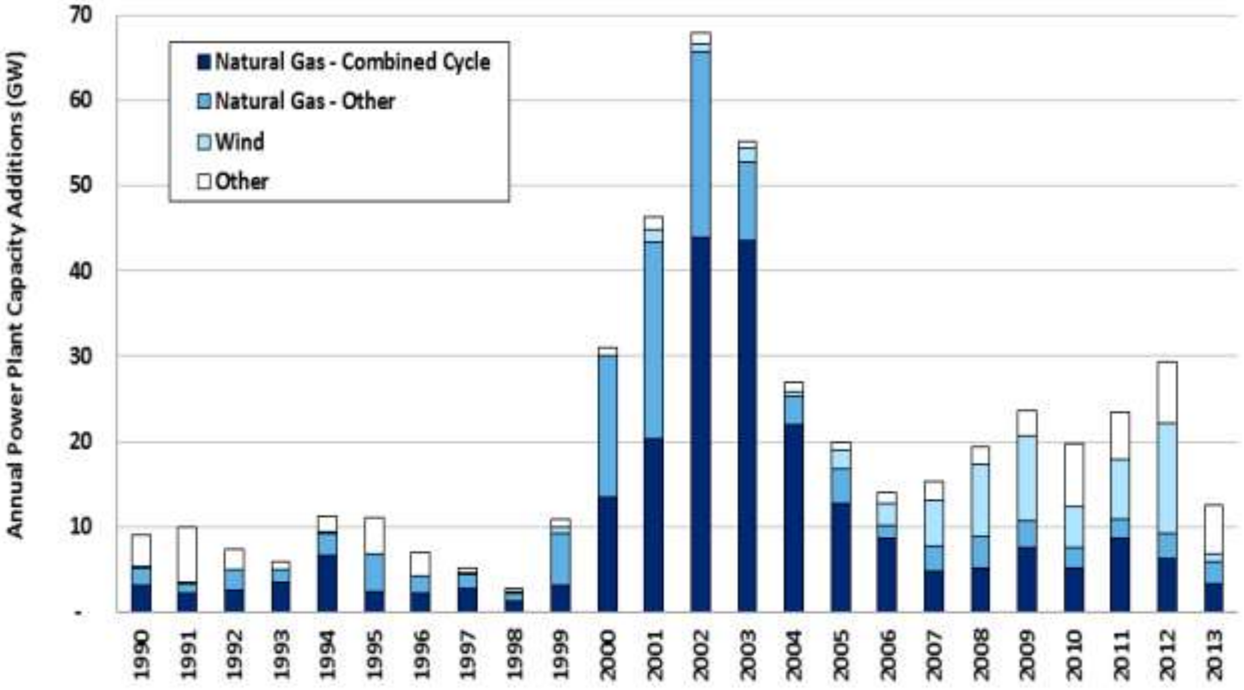

Figure 4: Historical power plant additions in the US since 1990 have been dominated by natural gas-fired facilities, with wind taking a larger share recently. Wind additions typically diminished at PTC expiration (Source: KAPSARC, using EIA data).

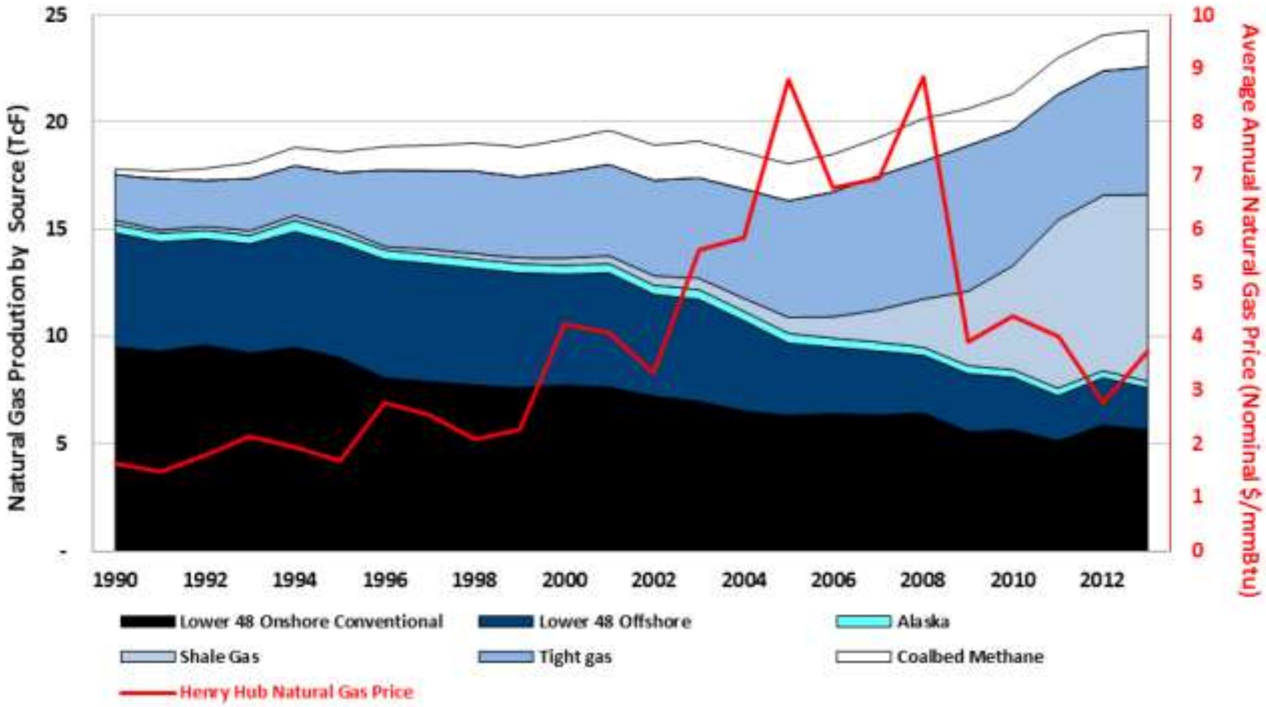

Figure 5: Historical US natural gas price and supply by source category for the years 1990 through 2013 (Source: KAPSARC based on EIA and BP 2013 Statistical Review of World Energy data).

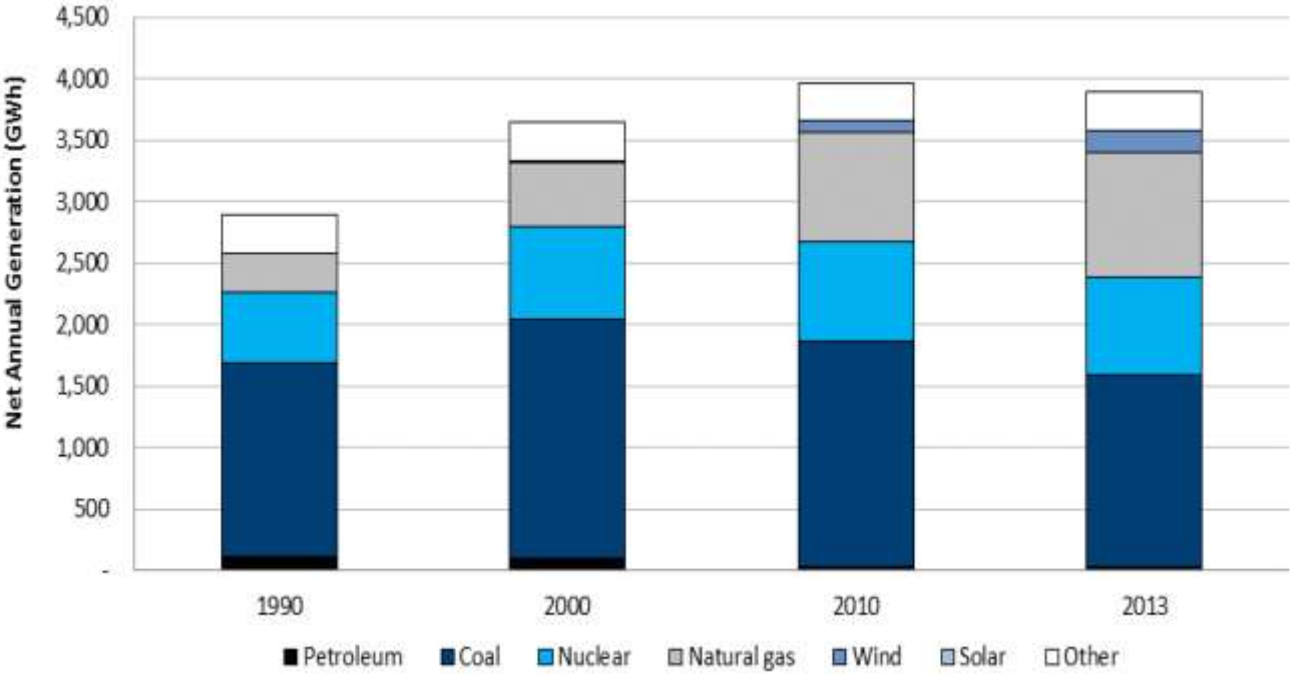

Figure 6: Historical generation in the US by fuel type (Source: KAPSARC based on the EIA March 2014 Monthly Energy Review data).

effect in renewable capacity investments as incentives expire (Figure 4). Today, as the PTC has not been renewed beyond 2013, power plant developers have turned much of their attention away from wind to natural gas facilities.

The natural gas spikes in 2004-2005 could have tempted policy makers to consider the job of advancing wind technologies done. But this would have been premature. The cost of producing electricity from wind is still much higher than that of natural gas-fired CC facilities. Incumbent technology innovation and supply chain development has caused a reduction in natural gas-fired CC levelized cost of energy (LCOE). Despite the considerable reduction in wind LCOEs, they were still significantly higher than their CCGT counterparts in 2012 with or without incorporating the policy support (Figure 7).

Discussion

Using two well-known renewable energy transition case studies, potential transformations in the competitive landscape that are typically overlooked in policy design have been identified.

Germany's energy transition journey exemplifies the complexities arising from trying to achieve local industry development targets and high penetration targets, simultaneously, within a tight timeframe. With hindsight, we can say that policy has overlooked the potential competitive pressures that could have arisen from global suppliers, inhibiting the achievement of local goals. Additionally, the German experience demonstrates how underestimating future cost reductions in the supported renewable technology can result in transmuting a reasonable financial incentive to a

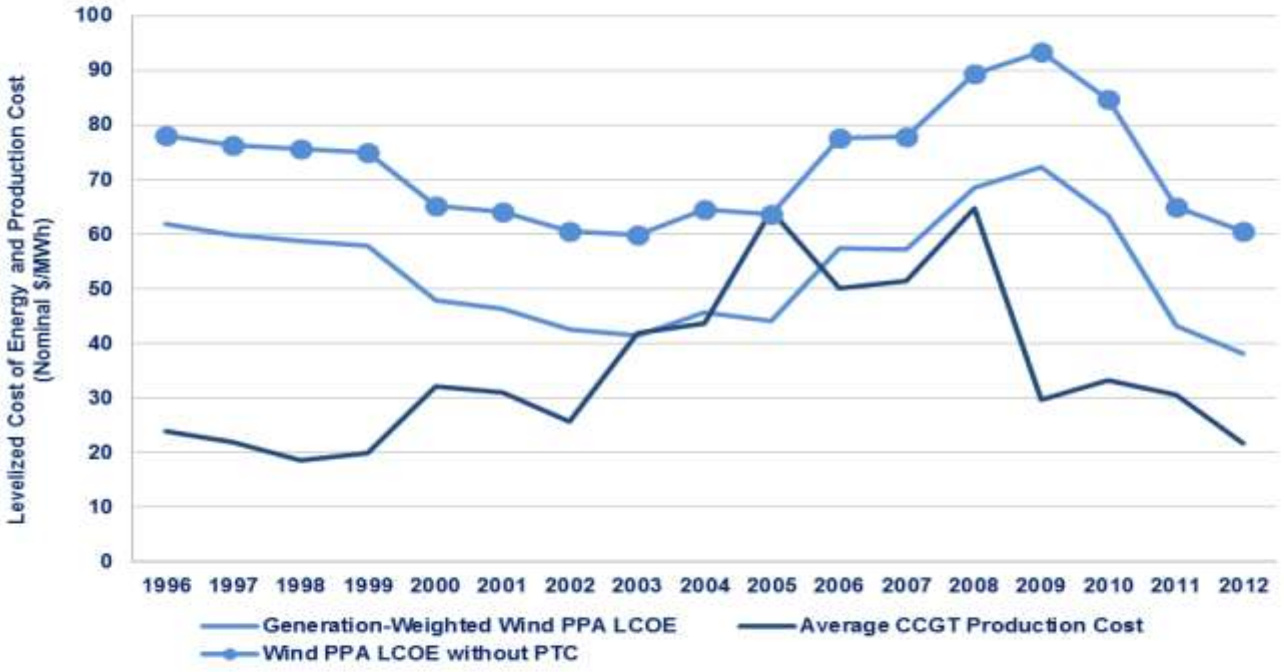

Figure 7: Levelized cost of energy of natural gas-fired combined cycle and wind technologies in the US (1996-2012). Source: KAPSARC using data from EIA, BP, Bloomberg New Energy Finance (BNEF) and Lawrence Berkeley National Lab (LBNL).

profligate one, and consequently causing political controversy while trying to agree on policy amendments. Scenario planning and asking 'what-if' questions are routes to mitigating the associated uncertainty. Equivalently, policies can be designed with flexibility attached to them to adapt for potential changing market conditions

In the US, regardless of the numerous federal and state policy instruments that were devised to support wind energy penetration, the natural gas value chain continued to improve its competitiveness in both the production of fuel and conversion to electric power – the supply cost curve moved downwards, even in the face of flat or growing demand levels. These improvements, which were not competitive reactions to wind industry growth, changed the landscape for all power generating technologies. We can imagine that this progress will continue, even assuming policy driven support for a new technology does not eat into the market share of the incumbent. It will therefore take longer than originally imagined by policy makers for the new entrant to become cost competitive in its own right. The high reliance of wind energy development on incentives for more than 20 years since the introduction of the wind PTC is an example. However, if the new entrant secures so great a penetration that demand for the incumbent begins to decline in absolute terms, the incumbent will move further down the supply curve to a lower marginal cost. This additional consequence of competition will further prolong the need for policy support for the new entrant.

The scale and duration of financial commitments by governments are undoubtedly an important aspect of any policy, and the case studies tell us that policy suppleness with respect to the finances can prevent creating political controversy at later stages of policy implementation. Two characteristics of a supple policy are of particular importance; the first is concerned with the ability to reduce or cease financial support dedicated to a specific technology if the technology costs fall for whatever reason. The German case-study (i.e. second blind-spot) reflects the value of this option in the face of technology costs falling faster than anticipated.

In the alternative case of renewable technology costs not falling as fast as those of incumbent fossil fuel supply chains, the danger is different. If the aim of policies supporting renewable energy is achieved – absolute reductions in consumption of fossil fuels – an economy may suffer higher energy prices than its competitors relying on fossil fuels. Renewables are only competitive with conventional fuels when their full cycle costs are comparable to the costs rather than the current market prices of fossil fuels. The continuing excess costs of renewables can only be borne by one of three stakeholders: investors (and their lenders), consumers, and taxpayers. There is no magical fourth source of funding. These higher energy costs are locked in once the capacity is installed, because of the high capital, low operating costs of wind and solar electricity. Furthermore, unless investors are coerced, there is a maximum contribution they will make based on their rate of return requirements. This leaves the balance to be shared between taxpayers and consumers, either directly or indirectly.

It is not hard to imagine that governments seeking to bolster their economies will succumb to the temptation to reduce the costs of support to their transition strategies. This may cause investors relying upon incentives to fill the cost gap in their economic comparisons of conventional and renewable energy to hold back or require levels of commitment that are politically difficult to provide. At least in the current economic climate, energy prices and taxes appear to exert more influence on an electorate, and thus their political leaders, than an appetite for a clean energy transition.

So what? Suggesting a Framework

Based on these three blind-spots presented, a general framework may aid policy makers in securing a higher likelihood of success. This reinforces the value of understanding, and being mindful of risk, uncertainty, and system effects.

- Risk effects can be predicted with some confidence, but deviations are also possible. The learning curve and economies of scale concepts are examples of this type of risk. It is reasonable to assume certain reductions in the manufacturing costs of a technology based on its learning curve, but there are no guarantees that these outcomes will occur exactly as predicted.
- Uncertainty effects are associated with events of an unknown probability distribution, including recessions, black swans, and radical engineering innovations.
- System effects are those associated with the market and its potential equilibrium, including the actions of other countries. Suppliers entering or leaving a market will affect prices and costs and alter the likelihood of achieving a target or the expense of doing so.

There is value to policy makers in assessing the effects of their policy on market equilibria conditions both domestically and abroad. They are less likely to be wrong footed if, beyond the current global supply and demand environment, they understand future targets that other countries have set for themselves. Next, the robustness of the policy choices under both risk and uncertainty effects can be assessed.

While the future cannot be predicted, policy makers can prepare to adapt and a degree of flexibility can be attached to policies to allow expected and unexpected future events to be tolerated and even to capitalize on them. This type of scenario planning can yield dividends. Wand and Leuthold (2014), for example, deduce a dynamic optimization model for examining policy effectiveness resulting from induced learning curves with an emphasis on the solar PV industry. They developed three self-explanatory scenarios: a ‘business-as-usual’ scenario, an ‘economic growth’ scenario, and a ‘sunny future’ scenario. Each scenario implied certain spending, penetration rates, and added generation. It was thus possible to formulate a general idea of each scenario’s outcome and the challenges for policy that would arise.

It appears that Germany’s EEG assumed only a business-as-usual scenario in initial policy design, while reality followed a sunny-future path, or at least an economic growth path. There was an opportunity to prepare for different futures than expected – the most robust policy would have been one that was resilient to a range of scenarios or one that identified the actions that would need to be taken should a deviation from the anticipated scenario arise and to incorporate it at an administrative, rather than legislative level.

Conclusions

An important lesson to be elicited from the case studies presented herein is that competitive pressures exercised on the new technology may be intentional or unintentional. These dynamics arise from myriad forces: domestic and foreign, technology- and market-driven. In the US, the advancements in CCGT and gas fracking technology have not occurred intentionally in retaliation to renewable energy development. By contrast, the expansion of the PV industry in China may have been a deliberate attempt to compete with the development of the PV manufacturing sector in Germany as part of China’s overall policy initiative to promote export-related industries to meet growth in global PV demand.

Policy makers are well advised to remember that demand for fossil fuels has been rising throughout the past decade, reducing the need to focus on competitiveness of such fuels to defend market shares. However, if transition policies are successful, there is no guarantee that this will continue to be the case. Demand on fossil fuels may clear lower down the cost of supply curves and, further, the curves themselves will likely move downwards as innovation counters the threat of extinction.

It may seem that this paper is contradicting itself by asking policymakers to try to anticipate dynamics that are difficult to foretell. While predicting the future accurately is impossible, it is both feasible and helpful to incorporate a range of potential scenarios for the evolution of the competitive landscape. Just because energy transitions may take longer and cost more in policy support than currently foreseen does not mean that they should not be undertaken. However, policies are more likely to be sustainable if they incorporate resilience to “inconvenient” outcomes as well as to the “preferred” state of the world.

Policies can be designed with flexibility to adapt to potential changes in the competitive landscape. Otherwise, policymakers may be criticized for shortcomings that were certainly evident with the benefit of hindsight but could also have been reasonably foreseen.

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