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Disputed wind directions: Reinvigorating wind power development in Taiwan

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ABSTRACT

This case study, which analyzes wind power development policy in Taiwan, investigates a theme that is commonly encountered by policy makers in a number of policy settings—how can appropriate policies be developed when two (or more) seemingly valid, yet disparate scientific or technical estimates confound objective analysis? The paper adopts the context of wind power development policy in Taiwan to demonstrate how to employ organizational analysis to identify factors which influence subjective assumptions underpinning disparate estimates of wind power potential and then demonstrates the application of two concepts from chaos theory – fitness landscapes and strategic real options – for guiding policy making despite the existence of technological dissent. In contrast to progressively declining feed-in tariffs that are commonly associated with fledgling renewable energy programs, this study introduces the concept of progressively escalating feed-in tariffs to encourage the development of mature markets—in this case, the Taiwan wind power market.

Introduction

After a cursory review of Taiwan's energy situation and its national energy strategy, wind power appears to be an obvious candidate for fast-track development policies. Key objectives of Taiwan's national energy strategy include enhancement of domestic power generation capacity, minimization of power generation costs, stabilization of fuel-stocks cost, and reduction of CO_2 emissions leading to a target of 50% of 2000 emission levels by 2050 (TBOE, 2009). With hydropower in Taiwan nearing maximum capacity, wind power is the only under-utilized utility-scale power source that possesses the attributes for meeting all these objectives. Yet, evidence indicates that the development of wind power in Taiwan has hit a plateau. Taiwan's only private wind power developer recently announced an intention to shift its operational focus to other national markets unless the government takes measures to improve the unprofitable business conditions for wind power in Taiwan (Lu and Ko, 2009).

Based on a series of semi-structured interviews with key stakeholders associated with power generation in Taiwan and a literature review which incorporated over 300 related news articles and academic studies, this case study examines wind power development in Taiwan. As the reader will learn, estimating wind power potential in Taiwan is a contentious issue. On the one hand, the Taiwan Power Company (Taipower) – Taiwan's public utility – estimates that wind power potential is moderate, and as a result, it prioritizes other technologies and other policies for achieving national strategic energy goals. On the other hand, Infravest – a private wind power developer – contends that wind power potential is much greater than Taipower estimates and harnessing this potential could contribute significantly to achieving national strategic energy goals. The theme of this paper focuses on the challenge of developing policy when confronted with two disparate technical estimates, both of which appear to be based on sound reason and judgment. Although the context of this paper centers on wind energy policy, the challenge of developing sound policy when two (or more) seemingly valid, yet disparate scientific or technical estimates confound objective analysis is relevant to policy makers in all fields.

One of the key contributions that this paper aims to make is to demonstrate how techniques attributable to chaos theory can be applied to the resolution of political deadlocks caused by dissenting yet equally plausible scientific evaluations. The paper also contributes to the propagation of knowledge for fostering renewable energy capacity expansion through policy instruments by introducing a new policy application for feed-in tariffs. Feed-in tariffs are typically seen as mechanisms for supporting the development of renewable energy technologies that are not yet commercially viable. Under such circumstances, an effectively managed feed-in tariff system incorporates mechanisms for gradually *reducing* the tariff in order to encourage developers of renewable energy technologies to innovate and minimize costs. In this paper, a feed-in tariff system is put forth as a mechanism for supporting market development of a mature technology, wind power. In this new application, the feed-in tariff system must incorporate a mechanism for gradually *increasing* the tariff in order to incentivize development of sites deemed commercially unviable.

In considering challenges to implementing the feed-in tariff system recommended in this paper, the study concludes with an

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examination of the concept of *strategic intent* which is a strategic management concept that advocates the importance of structural realignment to support changing strategy. In Taiwan's case, Taipower's strategic behavior to date has been entirely consistent with the government's mandate to enhance national energy security. If the government wishes to encourage Taipower to aggressively support the expansion of wind power capacity, it must re-align Taipower's strategic objectives and redesign incentive programs to encourage a more aggressive approach to seeking out new wind power sites.

The format of this study is as follows. The Taiwan energy situation section provides an overview of the power generation industry, describes the industry structure, summarizes strategic challenges relating to energy governance, and describes some of the programs designed to meet these challenges. The Wind power and Taiwan section provides an overview of wind power in Taiwan and analyzes two disparate estimates of realizable wind power potential. The analysis attempts to explain why these estimates differ and how this influences the policy-making process. The Designing policy amidst uncertainty section provides advice for Taiwan's energy policy makers in regard to how to proceed with wind energy policy development in the face of conflicting wind power potential estimates. In this section, concepts are borrowed from chaos theory to steer the policy-making process. In the Integration with the current system section, the recommendations put forth in the Designing policy amidst uncertainty section are discussed in relation to Taiwan's current feed-in tariff program. The discussion reveals how a new feed-in tariff program could be effectively appended to Taipower's current feed-in tariff. Finally, the Policy lessons learned section concludes with a summary of lessons that policy makers and analysts can glean from the Taiwan story.

Taiwan energy situation

Market overview

With just under 23 million living on a 32,000-km^2 island, Taiwan is one of the most densely populated nations in the world. It is also one of the world's most affluent nations with a per capita GDP of US $31,900 (PPP) in 2008 (CIA, 2008). The combination of a highly concentrated, affluent population, and an expansive industrial sector has inauspiciously fuelled Taiwan's ascension to become the world's third highest per capita consumer of electricity (TBOE, 2005), mushrooming from 2871 kWh/person in 1986 to 9977 kWh/person in 2006 (TBOE, 2007). Despite its comparatively small population size, Taiwan was the 17th largest national consumer of electricity in the world 2008, with aggregate electricity consumption of 233,000 GWh (CIA, 2008). Furthermore, as Fig. 1 illustrates, due to a proliferation of electricity-intensive industries, energy consumed for power generation is playing an increasingly dominant role in Taiwan's energy profile.

Taiwan is heavily dependent on imported fuel-stocks for power generation. Aside from electricity generated through hydropower and co-generation, the remaining 81.1% of electricity generated in 2006 employed imported fuel-stocks Table 1.

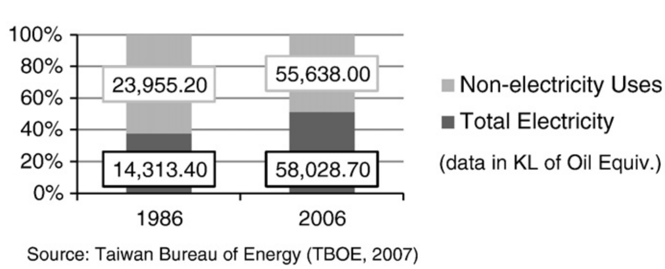

Fig. 1. The expanding role of electricity in Taiwan's energy profile.

Table 1
Taiwan's evolving electricity mix.

KL of oil equivalent					
Source of electricity	1986		2006		Average annual growth rate (%)
	KLOE	%	KLOE	%	
Conventional hydro	652	5	727	1	0.60
Coal-fired thermal	4686	33	22,821	39	8.24
Oil-fired thermal	1777	12	4798	8	5.09
LNG-fired thermal	–	0	8270	14	–
Nuclear power	7195	50	11,170	19	2.22
Solar and wind power	4	0	20	0	8.28
Cogeneration	–	0	10,224	18	–
Solar thermal	–	0	0	0	–
Total	14,313	100	58,029	100	7.25

Source: Taiwan Bureau of Energy (TBOE, 2007).

Although imports of coal have risen significantly in the 20-year period 1986–2006, growth in oil imports has slowed due to government efforts to replace oil-fired power with LNG-fired power. In terms of low-carbon power sources, national hydropower capacity has nearly reached peak potential, nuclear power capacity is expected to increase by 2.7 GW in 2011 when Taiwan's fourth nuclear power plant commences operation (TBOE, 2009) and renewables (solar and wind power) have been slow to develop as utility-scale power sources (TBOE, 2007).

The nation's reliance on fossil fuel energy for power generation (61.9%) fosters two noteworthy problems for Taiwan's energy policy makers. Firstly, the volatile nature of fossil fuel prices destabilizes industrial strategy and erodes corporate profitability. To date, such adverse impacts have been side-stepped by government regulatory refusal of Taipower appeals to pass along cost increases to end consumers (Shih, 2007). However, due to significant amplification of fossil fuel costs over the past 3 years, Taipower has suffered increasingly large financial deficits which must be reconciled through a drawdown of reserve capital. Losses of NT$23.25 billion (US $705 million) in 2006, NT$330 billion (US$10 billion) in 2007, and NT$130 billion (approximately US$4 billion) in 2008 have severely depleted Taipower's capital reserves thereby impairing financial well-being and raising concerns of insolvency, prompting Taipower's Vice-president of Finance Wen-Kuei Tsai to quip "If we close, who is going to supply electricity to the nation?" (Ho, 2007). The second problem related to Taiwan's reliance on fossil fuels is that Taiwan's per capita carbon dioxide emissions are enormous. In 2006, per capita CO_2 emissions in Taiwan (13.19 tonnes per capita) were the third highest in the world behind only Australia (20.58 tonnes) and the United States (19.78 tonnes) (Tchii, 2009). As Taiwanese President Ma Ying-Jeou asserted in a 2008 World Environment Day speech, although Taiwan is not a member of the UN, nor a signatory to the Kyoto Protocol, Taiwan has an obligation to the international community to take the matter of decreasing greenhouse gas emissions seriously.

Industry structure

Responsibility for the generation, transmission, and distribution of electricity in Taiwan has been historically vested with Taipower which is a public monopoly. Virtually all transmission and distribution lines in Taiwan are installed and owned by Taipower (Wang, 2006).

End-user electricity pricing is fixed by government energy regulators after consulting with Taipower and taking into consideration global energy pricing trends and the competitive needs of domestic industry. As alluded to earlier, Taipower faces extreme consumer and political antipathy regarding appeals to pass along cost increases to end consumers. Consequently, between 1983 and 2006, electricity prices in Taiwan were held unchanged. In July 2006, Taipei was allowed to raise its rates by 5.8% in order to compensate for increased fuel costs (Wang, 2008). Two subsequent price increases of

Table 2
Cost and retail price of electricity in Taiwan in 2008.[a]

Electricity source	Cost in US¢ per kilowatt hour[b]
Oil	¢15.33
Natural gas	¢17.82
Coal power	¢5.67
Nuclear (advanced technology)	¢1.88
Overall cost per kWh for Taipower in 2008	¢8.82/kWh
Average end consumer price	¢6.97/kWh
Average gross margin deficit per kilowatt hour	¢1.85/kWh

[a] These data were provided by Mark Chuang, Director of The Corporate Planning Department of Taipower, through personal e-mail correspondence on May 23, 2009.
[b] Calculated using the following exchange rate: US$1 = NT$33.

12.6% in July and October of 2008 have done little to attenuate operating losses. Table 2 indicates the extent to which electricity is underpriced. As the table illustrates, the shortfall between average cost and retail price in 2008 amounted to 1.85 US cents per kilowatt hour (kWh). With 233,000 GW hours of electricity consumed in 2008, this represents an aggregate operating margin deficit of US$4.255 billion. It is, however, worth noting that the cost estimates from Taipower in Table 2 are indicative of the politicized nature of energy pricing in Taiwan. Taipower claims that the cost of advanced nuclear power in 2008 was US¢1.88/kWh. Given that advanced nuclear power was estimated at US¢4.9/kWh in the US in 2007 (Sovacool, 2008) and advanced nuclear power in Japan cost approximately US¢6.4/kWh in 2007 (FEPC, 2008), this estimate is of dubious accuracy if it entails the total capitalized cost of advanced nuclear power. Nevertheless, although there is reason to doubt the accuracy of the nuclear cost estimate, the overall cost estimate and the average end consumer prices which provide support for the contention that Taipower is operating in deficit are subject to external auditing; and as a result, they are reliable.

Executives at Taipower face limited options for managing operational finances. In terms of retail price control, Taipower has to accept the prices set by government regulators. In terms of cost control over fuel-stocks, purchase prices of imported fuel-stocks are largely fixed through long-term supply contracts which are deemed necessary for supporting Taipower's main strategic remit to maintain a secure and reliable electricity supply.[1] Essentially, Taipower managers only have significant control over operating costs and capital equipment costs. Although government monopolies are infamous for cost inefficiencies, the recent financial deficits posted by Taipower are less attributable to operational inefficiencies than to the unenviable position of having to adhere to fixed retail prices in the face of amplified material costs.

In 1994, in a misguided attempt to improve market efficiency, the government partially liberalized the electricity market. Under this initiative, the electricity market was opened to independent power producers (IPP) and Taipower was required to sign 25-year power purchase agreements (PPA) with these power producers (Wang, 2006). As Table 3 indicates, approximately one third of Taiwan's power generation capability now rests with IPPs. The explanation for the success of the 1994 liberalization campaign is straightforward. Taipower is required to purchase electricity from IPPs at a price that equals the cost that Taipower incurs for generating electricity through similar technologies at its own facilities. Given the added costs associated with Taipower's mandate to ensure energy security, and with prices guaranteed for 25 years through PPAs, profits for IPPs are virtually guaranteed after winning contracts (Shih, 2007). Unfortunately, such a system does little to introduce competition to catalyze improvements in production efficiency at Taipower. In fact, diffusing

[1] Interview with Taipower executives on May 15, 2009.

Table 3
The expanding role of private electricity generation capacity in Taiwan.

	2000	2003	2005	2007
Taipower capacity (MW)				
Total hydro	4422.0	4502.0	4501.0	4513.0
Conventional	1820.0	1900.0	1899.0	1911.0
Pumped storage	2602.0	2602.0	2602.0	2602.0
Total thermal	17,819.0	17,886.0	19,231.0	21,016.0
Coal fired	8100.0	8100.0	8650.0	8800.0
Oil fired	5405.0	3563.0	3609.0	3610.0
LNG fired	4312.0	6223.0	6972.0	8606.0
Wind	–	2.0	18.0	131.8
Nuclear	5144.0	5144.0	5144.0	5144.0
Total Taipower	27,385.0	27,534.0	28,894.0	30,804.8
IPP capacity (MW)				
Thermal	7385.0	12,557.0	14,236.0	15,001.0
Cogeneration	5134.0	6807.0	7016.0	7781.0
IPPs	2250.0	5750.0	7220.0	7220.0
Hydro	–	8.8	10.7	22.2
Wind	2.6	6.1	6.1	55.9
Solar	0.1	0.5	1.0	2.4
Total non-Taipower	7387.7	12,572.4	14,253.8	15,081.5
Total capacity (MW)				
Total generation capacity	34,772.7	40,106.4	43,147.8	45,886.3
Total IPP share of capacity	21.2%	31.3%	33.3%	32.9%

Source: TBOE (2009).

power generation providers in this way likely undermines Taipower's economies of scale.

Present strategic challenges

Enhancement of national energy security dominates Taiwanese strategic energy policy. Taiwan's utter dependence on energy imports implies that adverse international energy market dynamics (over which Taiwan has no control) could deeply affect domestic socio-economic stability (Yue et al., 2001). Broadly speaking, there are two overarching objectives guiding Taiwan's national energy security strategy. Firstly, a series of strategic programs are in place to mitigate the risk of energy supply disruption. Secondly, strategic programs to mitigate the risk of energy price instability are also progressively unfolding. Fig. 2 outlines the five main program streams which support these two strategic objectives. The figure also provides some examples of key initiatives which fall under each program stream.

The program stream most relevant to renewable energy developers involves efforts to bolster Taiwan's indigenous supply of energy because Taiwan's dependence on imported energy ranks with Japan and Italy as being among the most precarious in the world. There are three major initiatives underway to upgrade indigenous energy supplies. The first initiative is the implementation of a Renewable Energy Development Bill that was finally passed in June 2009 after being mired in legislative debate for the past 7 years (Tchii and Wang, 2009). The bill formalizes a feed-in tariff system for renewable energy and establishes the legal basis for the creation of a pricing commission which will quantify feed-in tariffs for each form of renewable energy. The second initiative strives to strengthen Taipower's renewable energy development programs. In the short-term, Taipower plans to further encourage wind power capacity development, aiming for an ultimate goal of 2159 MW of installed wind power capacity by 2010 (Lin et al., 2009). However, as Chi-Yuan Liang, an economist at Academia Sinica, observes, achievement of this target is doubtful given that only 281 MW of installed capacity currently exists.[2] In the long term, Taipower is investing in solar photovoltaic (PV) power research because it is believed that solar PV power has the greatest

[2] Source: Bloomberg New Service, "Energy Bureau Looking to Boost Wind-Power 10-fold," 28 September 2007.

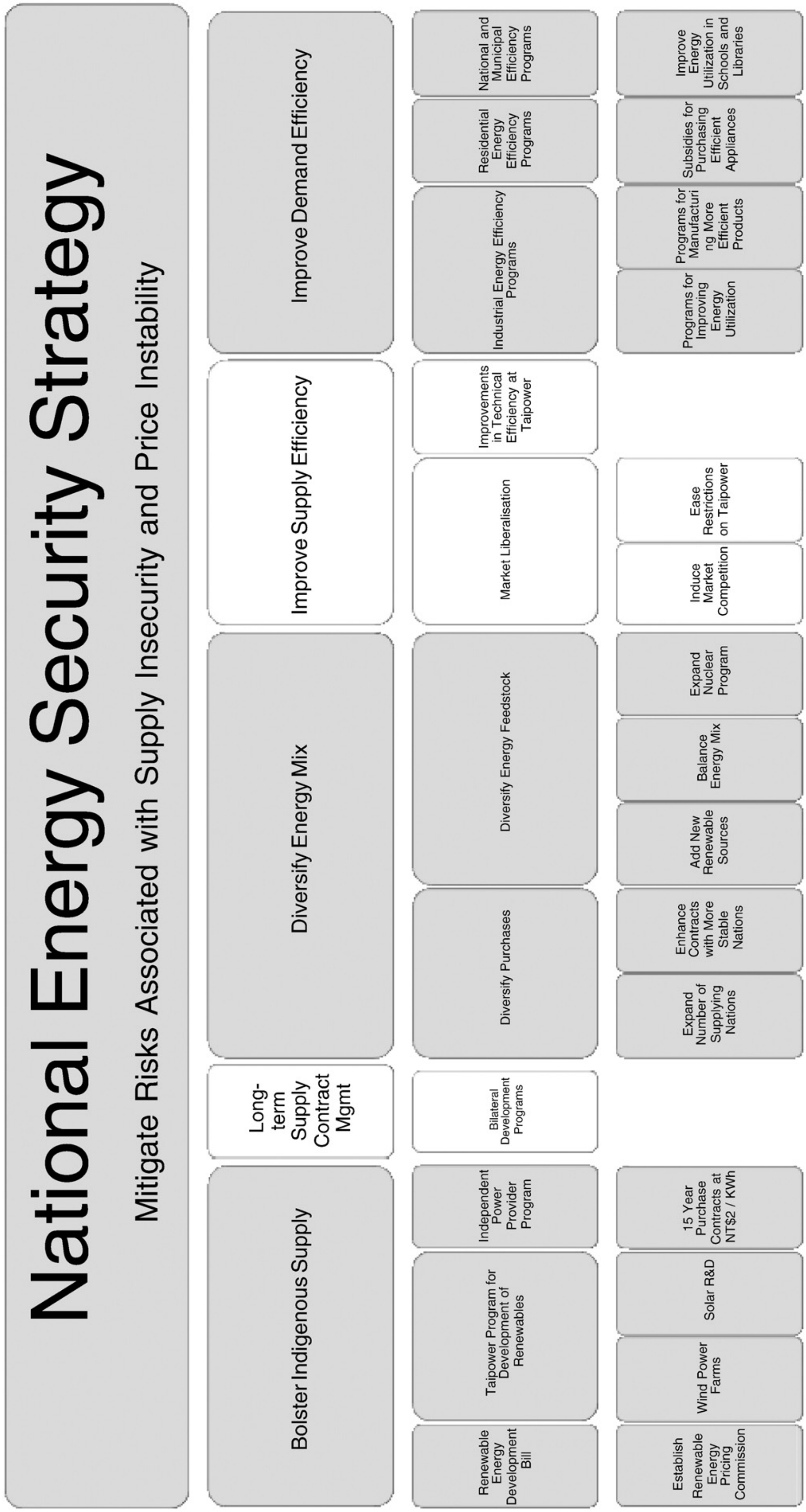

Fig. 2. Key elements of Taiwan's national energy security strategy.

potential of all current mainstream renewable energy alternatives.[3] The third initiative for enhancing domestic energy supplies entails augmentation of the IPP program. The government has proposed amendments to the Electricity Act which will make it easier for renewable energy providers to develop projects in Taiwan (Wang, 2006).

Another program stream of relevance to wind energy developers involves efforts to diversify Taiwan's pool of national energy suppliers and the type of energy that is purchased. In terms of diversifying national suppliers, Taiwan aims to reduce its dependence on Middle Eastern oil which accounts for 80.8% of its oil imports (TBOE, 2009). In terms of diversifying the energy mix, Taiwan is attempting to facilitate a transition from oil to LNG for power generation (Wang, 2006). Moreover, the role of nuclear power in the power generation mix will be fortified when the fourth nuclear power plant comes online in 2011 (TBOE, 2009). In terms of the role renewable energy will play in the diversified energy mix, Taiwan is aiming to increase the contribution that renewable energy makes to national power generation from 5.9% in June 2007 to 12% by 2020 (Lin et al., 2009; TBOE, 2009). While the bulk of current renewable capacity consists of hydropower (1922 MW of 2782 MW) (TBOE, 2008), wind and solar PV technologies are expected to contribute most to achieving the 12% target (TBOE, 2008).

The three other main program streams include initiatives to enhance efforts to improve right of access to foreign energy supplies, initiatives to enhance power generation efficiency at Taipower through technical upgrading, and initiatives to improved demand-side power utilization. Although initiatives to improve energy efficiency are typically seen as most cost effective, perceptions that renewable energy capacity is limited (to be further elaborated upon in the next section) place even greater impetus on embracing aggressive energy efficiency goals. The current objective is to improve energy efficiency by at least 2% per year based on 2005 energy intensity levels with an aggregate goal of reducing energy intensity to 50% of the 2005 level by 2025 (Taiwan MOEA, 2008). Already there are a number of programs in place to encourage improved utilization efficiency in industry, the residential sector and government circles (Shih, 2008).

In addition to the strategic challenges related to enhancing national energy security, politicians and citizens alike are beginning to view Taiwan's high per capita CO_2 emissions as a national mark of shame. Taiwan has struggled with decoupling electricity growth from GDP growth. For the past 25 years, the economic and CO_2 emission growth rates have paralleled one another with both measures increasing by over 400% between 1980 and 2006 (Shih, 2007). Despite the fact that Taiwan's diplomatic status prevents membership in international climate change mitigation regimes, Taiwan's current President Ma Ying-jeou, in an address at the National Energy Conference held in April 2009, announced commitments to stabilize CO_2 emissions at the 2008 level between 2016 and 2020, reduce national CO_2 emissions to the 2000 level by 2025, and to further reduce that amount by 50% by 2050 (Tchii and Wang, 2009). Given Taiwan's massive dependence on fossil fuels, this is a bold initiative that will require significant structural adjustments to Taiwan's power industry.

Evaluation of Taiwan's CO_2 emission reduction challenge

In interviews with executives of the Taiwan Bureau of Energy (TBOE) and Taipower, there was general agreement that many of the initiatives for enhancing national security would also contribute to CO_2 emission reductions. Progress in improving supply-side generation efficiency and demand-side energy utilization can help to attenuate the aggregate amount of energy used and, in doing so, reduce related CO_2 emissions. Initiatives to diversify the energy mix can also lessen CO_2 emissions. In particular, reducing reliance on oil by enhancing contributions from nuclear power, renewable energy, and LNG can facilitate sizable CO_2 emission reductions. However, executives at both the TBOE and Taipower were quick to point out that renewable energy potential was encumbered by land constraints and as such, the contribution that these technologies could make to CO_2 emission reduction was perceived to be marginal in comparison to improvements in energy efficiency or progress toward adopting a cleaner energy-mix profile.

Overall, there was a considerable amount of scepticism expressed by policy makers who were interviewed over the viability of achieving the President's penultimate CO_2 emission target of 50% of 2000 levels by 2050. A rough analysis explains the source of scepticism. Between 2000 and 2007, power generation capacity expanded by 32% (from 34,772 to 45,886 MW) to accommodate escalating power demands. If growth trends continue at a similar pace, over 240,000 MW of installed capacity would be required by 2050. If we optimistically assume that Taiwanese initiatives to improve supply-side and demand-side energy efficiency resulted in a doubling of energy efficiency (which would be an unprecedented national achievement), Taiwan would still require 120,000 MW of installed capacity to meet electricity demands in 2050. Evaluating the contributions each clean energy technology could make to the 2050 capacity estimate (120,000 MW) provides insight into the amount of fossil fuel energy that would still be required to meet electricity requirements. Table 4 summarizes the growth potential for each clean energy technology. Based on estimates provided by executives of Taipower and the Bureau of Energy, the maximum potential capacity for clean electricity amounts to 58,000 MW.

This informal analysis tells us that if the estimates of potential are accurate and barring major technological breakthroughs, an additional 62,000 MW of installed fossil fuel generation capacity would be needed to cover our hypothetical 120,000 MW capacity requirement for 2050. Even if Taiwan were to fulfill this additional capacity requirement by utilizing only LNG-fired power (in order to minimize CO_2 emissions), CO_2 emissions from the thermal power plants under this hypothetical scenario would still be roughly 30% greater than 2000 levels. As this hypothetical scenario illustrates, meeting the government's interim goal of reducing CO_2 emissions to 2000 levels by 2025 and the penultimate goal of reducing CO_2 emissions to 50% of 2000 levels by 2050 appears to represent Herculean challenges.

Whether or not Taiwan succeeds in its quest to meet its ambitious CO_2 emission reduction targets critically hinges on the accuracy of the maximum capacity estimates for each alternative energy technology represented in Table 4. As the above analysis indicates, if these alternative energy capacity estimates are accurate, then even the achievement of unprecedented gains in energy efficiency improvement will fail to come close to the established targets.

Table 4
Growth potential of alternative energy technologies in Taiwan.

Alternative energy technology	Maximum capacity potential by 2050	Source of estimate
Wind power	3000 MW	Taipower (assuming advances in technology)
Solar, geothermal, tidal power	3000 MW	Bureau of Energy targets
Hydro power	5000 MW	Extrapolation of growth trend
Cogeneration	30,000 MW	Optimistically assuming a 400% growth in capacity
Nuclear power	17,000 MW	Taipower estimate of capacity expansion potential for current sites (20 reactors)
Total clean energy	58,000 MW	

[3] Interview with Taipower executives on 15 May 2009.

Perusing the capacity estimates presented in Table 4, the wind power capacity estimate appears to be particularly conservative. In terms of facilitating a transition away from fossil fuel energy, wind power is the proverbial "low hanging cherry" on the tree of options. Globally, wind power is now commercially competitive with LNG-fired and oil-fired power (DeCarolis and Keith, 2006; Morthorst and Awerbuch, 2009). If the cost of social and environmental externalities associated with fossil fuel combustion are factored into a cost comparison, wind power is also commercially competitive with coal-fired power (Sovacool, 2008). Given the commercial viability of this clean energy resource, nations which are endeavoring to expediently bolster renewable energy capacity should strive to fully exploit the potential capacity of wind power. If wind power capacity in Taiwan could be expanded to capacity levels found in vanguard nations such as Denmark and Germany, 20–30% of total power requirements could be met through this one energy source. Accordingly, one of the crucial questions that should be asked in regard to renewable energy development in Taiwan is "What is the reason for such a low wind power capacity estimate?".

As this analysis of wind power policy in Taiwan will illustrate, in attempting to answer this question, a series of intriguing insights will emerge in regard to policy making amidst technical uncertainty. The Taiwan wind power story should encourage policy makers to consider how the existence or absence of technical information influences their policy realms. Moreover, the recommendations put forth for guiding policy makers in designing policy amidst uncertainty are strategic management techniques that can be readily adapted to policy design and implementation in any number of policy fields. In short, what follows is a story of wind power development in Taiwan, but application of the recommendations put forth is relevant to all policy makers.

Wind power and Taiwan

Market overview

Government policy has significantly influenced the development of Taiwan's wind power industry. In May 1998, the government announced a renewable energy expansion plan aimed at boosting the renewable energy supply to 3% of total power generation by 2020 (Tsai, 2005). In March 2000, The Bureau of Energy announced a support program for wind power demonstration projects which included subsidies of up to 50% of the installation cost for wind power demonstration systems (up to a maximum subsidy of NT$16,000 (US $480) per kilowatt) (Huang and Wu, 2009). This catalyzed a number of wind power demonstration projects and by the end of 2003 installed wind power capacity amounted to 8.54 MW (Tsai, 2005). In 2002, the Renewable Energy Development Bill mentioned earlier was drafted which put forth policies to support more vigorous development of renewable energy projects (Wu and Huang, 2006). While the bill was being debated in the Executive Yuan, Taipower announced interim plans to offer 10-year energy procurement contracts at a contract price of NT$2 (approximately US¢6.16) per kWh (Wu and Huang, 2006). The contractual period has been subsequently extended to 15 years (Lin et al., 2009). This procurement program accelerated wind power capacity expansion. In 2004 alone, 18 MW of wind power capacity was installed.

Table 5
Wind power facilities in Taiwan.

Wind farm	Developer	Number of turbines	Total capacity (MW)
Penghu Jhongtun: Phase 1	Taipower	4	2.4
Shihmen (1st NPP)	Taipower	6	3.96
Hengchun (3rd NPP)	Taipower	3	4.5
Penghu Jhongtun: Phase 2	Taipower	4	2.4
Taoyuan Datan	Taipower	3	4.5
Taoyuan Dayuan-Guanyin	Taipower	20	30
Taichung Power Plant	Taipower	4	8
Taichung Harbor	Taipower	18	36
Changbin Industrial Park	Taipower	23	46
Hsinchu Siangshan	Taipower	6	12
Yunlin Mailiao	Formosa Heavy Industries Corp.	4	2.64
Hsinchu Chunfong	Cheng Loong Corp.	2	3.5
Miaoli Jhunan	InfraVest GmbH	4	7.8
Miaoli Dapeng	InfraVest GmbH	21	42
Changbin Lugan	Luway/InfraVest GmbH	33	75.9
Total		155	281.6

Source: TBOE (2008).

Table 6
Wind power onshore facilities under development in Taiwan.

Stage of development	Number of projects	Total capacity (MW)	Share of total capacity (in MW): Taipower	Share of total capacity (in MW): Private sector
Planning	119	239.5	70.8	168.7
Consent	71	149.5	68	81.5
Construction	40	78.8	35.1	43.7
Total	230	467.8	173.9	293.7

Source: TBOE (2008).

Although the Renewable Energy Development Bill was finally approved in June 2009, the development of feed-in tariffs will take some time because an energy commission needs to be set up to consider the appropriate pricing levels. In the meantime, Taipower's interim program for purchasing wind energy at US¢6.16 per kWh is still stimulating development. Despite criticism that the purchase price of US¢6.16 per kWh is too low to stimulate large-scale investment (Lu and Ko, 2009), wind power capacity in Taiwan continues to expand. As of 2008, there were 155 wind turbines amounting to 281.6 MW of installed capacity at various locations around Taiwan (see Table 5).

In addition to current installations, 230 onshore wind turbines sporting combined capacity of 467.8 MW are now at various stages of planning or construction (see Table 6). Additionally, Taiwan's first offshore wind power development which will total 300 MW of wind power capacity has recently been ratified by the Executive Yuan and is now in the initial stages of planning. When these projects are completed, Taiwan will be able to boast a total installed wind power capacity of 1049.4 MW (TBOE, 2008).

As a result of these positive developments, the Taiwanese government has raised its long-term target capacity target for renewable energy to 10% of total electricity capacity by 2010 and 12% of total electricity capacity by 2020 (TBOE, 2009). The anticipated contribution from wind energy has been estimated at 2159 MW of installed capacity by 2010. This amounts to 42% of the 2010 target for renewable energy (5130 MW). Coupled with the current installed capacity for hydropower of 1911 MW (see Table 3), wind and hydropower together are expected to account for 79% of installed renewable energy capacity in 2010 (Lin et al., 2009).

In terms of aggregate national wind power potential estimates, excellent wind potential can be found along Taiwan's western coastline, its southern peninsula, and several small surrounding islands. These areas are characterized by wind speeds that are greater than 4 m/s at 10 m above ground (Chang et al., 2003). Moreover, many prospective sites in Taiwan feature between 3000 and 3500 h per year of harvestable wind.[4] Unfortunately, the majority of Taiwan's

[4] Interview with Chun-Li Lee, Senior Specialist, Taiwan Bureau of Energy on May 13, 2009.

population resides along the western coastline. Therefore, although technical potential for wind energy in Taiwan may be high, competing land uses severely limit exploitable capacity (Yue et al., 2001).

Estimates of wind power potential for Taiwan are both disparate and contentious. Taipower, for example, estimates that total *technical* potential for wind energy in Taiwan is 4600 MW of onshore potential and 9000 MW of offshore potential. However, when factoring in current land-use restrictions, the economic viability of siting wind turbines in various locations and competition for development, Taipower contends that only a portion of total technical potential is currently realizable and that realizable potential is somewhat malleable because improved economic conditions tend to enhance realizable potential. Taipower estimates that current realizable wind energy potential amounts to 1000 MW onshore and 1200 MW offshore after factoring in development limitations. This implies that the government target for 2010 of 2159 MW represents nearly full exploitation of realizable potential under current economic conditions. If Taipower's estimate for total realizable wind power of 2200 MW is accurate, full exploitation would amount to 4.8% of 2007's installed electricity generation capacity (Table 3; 2007 data). Moreover, when the projects that are currently in development are finally completed, 75% of onshore realizable potential and 25% of offshore realizable potential will be exploited.

On the other hand, Karl-Eugen Feifel of Infravest (Taiwan's only private wind power developer) estimates that 3000 MW of onshore wind power and 5000 MW of offshore wind power could be feasibly *realized* if Taipower increased its wind power procurement rate from the current level of US¢6.06 per kWh to US¢12.12 per kWh. This procurement rate would still be considerably less than the rate at which Taipower generates oil-fired power, which is US¢15.33/kWh (Table 2). Infravest contends that procurement rates that exceed US¢ 8.48 per kWh would begin to make inland projects financially viable and intensify project activity. If Infravest's estimate for total realizable wind power of 8000 MW is accurate, full exploitation of all wind power potential would amount to a robust 17.4% of 2007's total installed electricity generation capacity. Under Infravest's projections, when the projects that are currently in development are finally completed, only 25% of realizable onshore potential and 6% of realizable offshore potential will be exploited.

The importance of wind power in contributing to Taiwan's CO_2 emission reduction efforts varies significantly depending on which of these two estimates best approximates reality. Moreover, the nature and intensity of government policies for expediting wind power expansion would likely differ depending on which estimate is accurate. If the Taipower estimate of realizable potential is accurate, one could argue that Taipower has done a superb job of reducing the cost of wind power procurement while fostering capacity development programs that have nearly fully tapped onshore wind potential. In such a case, the main policy challenges going forward would be (i) to design a feed-in tariff system to encourage the development of offshore wind power projects which are typically more expensive to construct and (ii) to sweeten the incentives for onshore wind power development in order to encourage developers to harness the remaining 25% of onshore potential which likely includes less financially lucrative wind farm sites. Conversely, if the Infravest estimate for realizable wind energy potential is accurate, a great deal of wind power potential remains untapped. Under this scenario, maximizing wind power capacity could contribute significantly to CO_2 emission abatement; therefore, the main policy challenge going forward would be to design bold development policies in order to amplify the pace of wind power development.

Evaluating disparate projections for wind power potential

In comparing Taipower and Infravest estimates of realizable wind power potential, the primary source of disparity appears to stem from differing assumptions made when deriving *realizable* potential from *technical* potential. As Table 7 illustrates, if one were to assume that the Taipower estimates for *total technical potential* are reasonably accurate, as we have assumed in this paper, the *realizable* potential estimates from Infravest are considerably bolder than the Taipower estimates. The most obvious reason why these estimates would differ stems from the economic assumptions each party makes because typically in wind power markets, higher procurement prices make previously unviable sites viable, thereby enhancing realizable potential estimates. Infravest's estimate for realizable potential is based on a specific end-price scenario (US¢12.12 per kWh) and reflects what Infravest believes is achievable if the government were to raise the purchase price for wind power. Although Taipower executives did not explain the rationale for their estimate of realizable potential, their estimate appears to be based on the current procurement price of US¢ 6.06 per kWh which even Taipower executives admit is too low. In short, the Taipower estimate appears to reflect a degree of insouciance toward wind power development. One possible explanation for this is that nuclear power expansion is both anticipated and supported by Taipower executives. Accordingly, wind power may be viewed as an added threat to the nuclear power development program which is already a hotly contested political issue. However, as the following paragraphs will illustrate, competing economic assumptions do not tell the whole story. Influences arising from disparate organizational characteristics also impact estimates of realizable potential.

Infravest's first wind power project was in Germany. Executives in the firm possess extensive knowledge regarding the evolution of the German wind power industry. As such, projections for realizable wind power potential in Taiwan are likely influenced by the German precedent of how a wind power market can flourish under proper market incentives. Indeed, in an interview with Infravest Chairman Karl-Eugen Feifel, who is a German national, he specifically drew attention to the history of wind power development in Germany to emphasize how inland sites that typically exhibit inferior wind quality can develop in the presence of commercially attractive feed-in tariffs. Experience with the evolution of the wind power market in Germany also provides Infravest with one other insight regarding the nature of wind power development. In Germany, commercially attractive feed-in tariffs encouraged German farmers to organize cooperatives to invest in wind turbines as a secondary source of income from existing farmland (Komor, 2004). This phenomenon enhanced the amount of *realizable* potential because it added a number of existing agricultural plots to the pool of prospective sites. Typically, conservative estimates of realizable potential would exclude such land that is already reserved for other uses. It is very likely that Taipower's estimate of realizable potential has underestimated the potential for siting wind turbines on existing agricultural plots. Overall, it can be surmised that Infravest's estimate of realizable wind power potential in Taiwan is

Table 7
Comparing estimates of realizable wind power potential in Taiwan.

	Technical potential (MW) (Taipower)	Realizable potential (MW) (Taipower)	% of technical potential	Realizable potential (MW) (Infravest)	% of technical potential
Onshore	4600	1000	21.7%	3000	65.2%
Offshore	9000	1200	13.3%	5000	55.6%
Total	13,600	2200	16.2%	8000	58.8%

influenced by experience with developing wind power in other countries that may or may not be fully applicable for Taiwan.

Regarding Taipower's estimate, there is evidence to indicate that organizational characteristics induce conservative estimation of realizable wind power potential. One of the key mandates of public monopolies is to safeguard the public interest. Taipower's mandate is no different. Its priority is to enhance energy security. Accordingly, the ideological approach embraced by Taipower strategists is significantly different than the ideological approach that strategists from a private utility operating in a liberalized market would adopt. A comparison of probable strategic behavior illustrates the relevance of this ideological difference for estimation of realizable wind power potential. The purported cost of LNG-fired power in Taiwan is US¢17.82/kWh, while the procurement cost of wind power is set to equate with the cost of generating wind power at Taipower owned wind farms, US¢6.06/kWh. A profit-seeking utility that is less concerned about enhancing energy security would seek to substitute wind power for LNG-fired power in order to maximize profitability. Assuming that the average wind turbine can generate 2190 h of capacity power per year (applying an average capacity factor of 25%), for each 1000 MW of wind power capacity that replaces LNG-fired power, the utility would save US$257.5 million per year.[5] With cost savings of this magnitude, a profit-seeking utility would aim to maximize capacity expansion of wind power at the expense of LNG-fired power. For aggressive firms, this may threaten the integrity of the electricity grid because of the importance of LNG-fired power in supporting peak-load fluctuations. Wind power cannot serve the same function (Boyle, 2004). Conversely, Taipower has resisted such a substitution strategy because the forces which catalyze profit-seeking behavior (i.e. lucrative bonuses and promotions based on profit maximization) are not the primary forces governing strategic behavior at Taipower. Although Taipower executives may be somewhat incentivized to improve financial performance, they are primarily evaluated on performance in relation to preserving national energy security. This ideological difference influences Taipower's perspective on wind power potential because their strategic planners are less incentivized to ferret out all wind power development options. On the other hand, profit-seeking firms would be much more aggressive in identifying new sites to exploit and as such, would be more apt to produce more vigorous estimates of realizable potential.

Another organizational characteristic which likely dampens Taipower's estimate of realizable wind energy potential is a more conservative perspective on managing public opposition in comparison to the prevalent perspective at Infravest. Infravest largely views public opposition as a commercially resolvable hurdle. As the Chairman of Infravest pointed out in an interview, opposition to wind power developments is frequently resolvable through compensatory payments made to dissenting parties.[6] On the other hand, Taipower's perspective reflects the government's aversion to public antipathy. Public opposition to energy projects is something to be avoided if possible. These divergent perspectives on managing public opposition influence the estimation of wind power potential because a component of any realizable potential estimate includes assumptions regarding the amount of technical potential that could be harnessed without incurring public opposition. For example, during an interview with an official at the Bureau of Energy, it was mentioned that an environmental group had recently lodged an objection to offshore wind power development due to concerns that such developments could adversely affect the habitat of an endangered marine mammal, the white-beaked dolphin. The official pointed out that if the concern is validated, prohibitions to offshore wind power developments in certain areas may be inevitable.[7] Therefore, the Taipower estimate may exclude sensitive marine habitats, while the Infravest estimate might not.

Although there may be other ideological differences between Taipower and Infravest which further induce disparate assumptions upon which realizable wind energy potential is estimated, the examples provided above are sufficient for qualifying the nature of the two estimates. The Infravest estimate can be considered to be a best case scenario predicated on the assumption that the Taiwanese wind power market will respond similarly to the German wind power market if proper market development incentives are enacted. Meanwhile, the Taipower estimate can be considered to be a highly conservative estimate that has been significantly tempered by organizational characteristics which encourage guarded projections.

In summary, seeking to understand the ideologies guiding behavior within an organization sheds light on its strategic behavior. In this case, such an analysis helps us to conclude that actual realizable wind energy potential in Taiwan is likely considerably more than 2200 MW projected by Taipower; however, it may not be as high as Infravest estimates, 8000 MW. What our analysis fails to do is to give us an accurate indication of where actual realizable wind energy potential lies on this spectrum. Accordingly, it may seem logical on the surface to recommend that the government commission one or more additional independent studies of wind energy potential in Taiwan.

The problem with funding additional wind power potential studies is that the resultant estimates will likely be no better than the Taipower or Infravest estimates at predicting actual realizable potential. This is because the accuracy of such estimates is dependent on the nature of subjective assumptions made when estimating both technical potential and realizable potential. For example, in estimating technical potential, an estimate based on an assumption that the average rated turbine capacity in the future will be 4 MW (which is a reasonable assumption given that 5 and 6 MW systems are currently being produced) could wind up being 100% higher compared to an estimate which assumes the average rated turbine capacity will be 2 MW (which may be the most economical size in the future), depending on estimates made in regard to how many turbines are clustered together and what the spacing is between the turbines. Similarly, assumptions made regarding the degree to which technically feasible sites can actually be developed will have a huge impact on final capacity estimates.

Updating an older study of realizable wind energy potential in Taiwan serves to illustrate the impact that assumptions can have on final estimates. In 1999, the Taiwan Energy Commission (the predecessor of the Bureau of Energy) commissioned a study which concluded that there was 8046 km^2 of land in Taiwan graced with average wind speeds greater than 4 m/s at 10 m heights. In estimating onshore wind power potential, researchers assumed that the rated capacity of the average wind turbine would be 1.8 MW and that only 2.5% of 8046 km^2 could be earmarked for wind farms due to competing land uses, site impracticalities, land-use restrictions, etc. In estimating offshore potential, the researchers concluded that 700 km^2 of coastal seabed in areas of suitable wind quality were accessible at depths less than 15 m. The researchers further estimated that only 10% of the 700 km^2 could be exploited due to practical constraints such as access limitations, interference with shipping lanes, etc. In aggregate, the study concluded that there were 1667 MW of onshore wind power potential and 2333 MW of offshore potential (Yue et al., 2001).[8]

[5] Based on the following equation: ((capacity factor × total hours in a year × total installed capacity in MW × 1000) × (cost of LNG − cost of wind power)), which yields ((0.25 × 8760 × 1000 MWh × 1000) × (0.1782 − 0.0606)) = US$ 257.5 million per year.

[6] Interview of May 14, 2009.

[7] Interview with Bureau of Energy officials on May 13, 2009.

[8] It is interesting to note that in the decade that has passed since the Energy Commission sponsored this study, the assumptions regarding realizable potential have clearly become more conservative. The study concluded that total realizable wind power potential was 4000 MW. Taipower now estimates the total realizable wind power potential to be 2200 MW.

If the 1999 estimate for onshore potential was recalculated under the assumptions that the average rated turbine capacity would be 3.6 MW (which is currently feasible), that the increase in turbine size would result in 33% fewer total turbines placed across the country and that 4% of the land exhibiting average wind speeds of greater than 4 m/s could be developed (which is the norm used in German calculations) (Yue et al., 2001), the estimate for onshore wind power potential would increase from 1667 to 3574 MW.[9] Furthermore, if the 1999 estimate for offshore potential was updated to incorporate advances in turbine technology, reworking the calculations based on an average rated turbine capacity of 4 MW (the emergent norm for offshore turbines) would be reasonable. Moreover, due to advances in platform technology, revising the estimate of exploitable area from 10% to 20% of the 700 km^2 could be justified. Under these revised assumptions, the offshore wind power potential would be revised upward from 2333 to 6947 MW if we were to once again assume that the increase in turbine size would result in 33% fewer total turbines placed across the country.[10] In short, a revised set of assumptions would increase the 1999 estimate of total realizable wind power potential in Taiwan from 4000 to 10,521 MW. Under these revisions, Taiwan would be transformed from a nation with negligible wind power potential to a nation in which wind power could contribute significantly to national power generation.

The point of this illustration is not to introduce yet another estimate of realizable wind power potential in Taiwan but to highlight the point that estimates of wind power potential are dependent on the nature of assumptions made in regard to the variables included in the estimates. In turn, such assumptions are heavily influenced by ideological biases and vested interests. So where does this leave Taiwanese policy makers who wish to have as accurate an indication as possible regarding realizable wind power potential in order to ascertain the contribution that wind power could make to a fuel import reduction and CO_2 emission reduction strategy and design appropriate policies to guide wind power expansion?

Designing policy amidst uncertainty

The absence of a scientifically objective estimate for wind power potential places Taiwanese energy policy makers in the unenviable position of having to develop policies amidst an environment of uncertainty. As undesirable as this position may be, developing policy in an environment of uncertainty is a common challenge for policy makers. Although the elements of uncertainty may differ, policy making almost always occurs in complex, dynamic environments (Cohen et al., 1972). When developing strategies for complex, dynamic environments, insights from chaos theory can prove useful.

Fitness landscapes

Eric Beinhocker (1999) describes a complex, dynamic business environment as being analogous to a geographic landscape (which he calls a "Fitness Landscape") that is constantly changing due to volcanic activity and plate tectonics. He posits that the task of accurately predicting where the tallest mountains will emerge (which is his analogy for a prime emergent market opportunity) is unfeasible due to the complexity of latent forces. Consequently, the best strategic approach for operating in a complex, dynamic environment is to utilize available information to predict areas of likely emergent activity (in his analogy this is accomplished by identifying geological conditions conducive to mountain formation) and prepare the firm for rapid response when opportunities do emerge. Applying this approach to the challenge faced by Taiwanese energy policy makers, a program could be implemented to stimulate wind power development and monitor the pace and scope of activity. Policy makers should then be prepared to enhance the stimulus measures should the pace or scope of activity fail to meet expectations. Given that the preferred policy instrument for stimulating wind power development in Taiwan has been a feed-in tariff, it would be a logical extension of this policy to prime wind power development by increasing the feed-in tariff rate. The natural question that arises when pondering an increase in the feed-in tariff rate is, *What level of increase should be implemented?*

Real options

Another perspective on developing strategy in complex, dynamic business environments provides guidance for addressing this question. Robert Grant (2005) in a leading textbook on strategic analysis describes a concept that he refers to as *real options*. A *real option* is essentially a risk mitigation technique for uncertain environments that is modeled upon the underlying principle of stock options. The idea is to limit risk exposure by implementing conservative programs that permit strategic forays into areas of promise without incurring full financial risk. As performance data emerge, managers begin to revise and reset strategic direction. The revised strategies catalyze new outcomes which are then evaluated and the process begins a new iteration.

A real options strategy is applicable to public policy circumstances in which a general program direction is understood to be desirable but the overall impact of program implementation is not fully predictable. An underlying premise of a real options strategy is acceptance that program implementation in complex, dynamic policy settings will never produce optimal results due to the confounding influence of unforeseen variables. Consequently, optimizing policy in such a policy setting is done by making small adjustments to the existing program as information emerges regarding performance of the program.

Examining what a real options strategy is not helps to shed light on what it is. A real options strategy is not a workable approach for situations that require emergency response. For example, it would not be acceptable to test *potentially suitable* policy responses in addressing an outbreak of avian flu. A real options strategy is also not a "ready, fire… aim" strategy. Prior to implementing a real options strategy, extensive background research is required in order to develop the best possible policy design. With a real options strategy, there is clear initial direction; however, there is also an understanding that initial program implementation may not be the most effective solution. It is an "aim, fire, re-aim, fire" strategy. A real options strategy is also not a strategy that can be applied to situations involving dichotomous outcomes (i.e. live or die; pass or fail, etc.) because such situations are optimized when the favored outcome is produced-there is no scope for adjusting the policy to optimize the outcome. Lastly, a real options strategy is not a "satisficing" strategy which is deemed successful upon producing satisfactory results. Rather, a real options strategy is an iterative process that begins with an initial policy based on best available data and then progresses to a performance evaluation stage which subsequently lead to program refinements in order for the cycle to begin again. It seeks to produce optimal results over time.

Applying chaos theory to wind power development policy

Relating the concept of real options to the challenge of establishing a new higher feed-in tariff rate, policy makers would be best advised

[9] Based on the following equation: (1999 onshore potential × proportional increase in rated turbine capacity × ratio of new turbines to old × proportional increase in estimate for exploitable land), which yields (1667 MW × 2.0 × .67 × 1.6).

[10] Based on the following equation: (1999 offshore potential × proportional increase in rated turbine capacity × ratio of new turbines to old × proportional increase in estimate for exploitable land), which yields (2333 MW × 2.22 × 0.67 × 2.0).

to initiate a moderate increase that is high enough to capitalize new activity but not too high to significantly alter Taipower's cost base. It is time well spent to try and seek an optimized price for encouraging inland development because for every 1000 MW of installed capacity, every US¢1/kWh increase in a feed-in tariff will cost Taipower US $21.9 million in forgone revenue.[11]

There are a number of possible methods for identifying a suitable feed-in rate increase. One method of establishing a feed-in tariff that will catalyze inland development exploits Taipower's own competency in wind power development. Taipower could establish an inland wind farm of its own in order to ascertain its cost and then base the revised feed-in tariff on this cost. A rough projection based on feedback from interviews indicates that the cost of generating wind power from an inland site plus the addition of a small mark-up to induce private development suggests a wind power cost of approximately US¢9.09/kWh, which is 50% higher than the current feed-in tariff. Given that feed-in tariffs in countries such Germany, Belgium Portugal, France, and Spain all exceed US¢12/kWh,[12] an initial increase to US¢9.09/kWh would represent a conservative "real option" adjustment that will catalyze new development.

Monitoring systems should be established prior to implementation of the initial feed-in tariff rate increase in order to evaluate performance of the enhanced rate (Mallon, 2006). Tracking the growth rate in applications for wind power development permits might be the best benchmark for monitoring the effectiveness of the new feed-in tariff. When applications for wind power development permits begin to exhibit a trend toward unabated decline (i.e. 6 months of progressive decline), it indicates that a further increase in the feed-in tariff may be required to encourage accelerated development. However, as was the case with the initial feed-in tariff rate increase, any additional increases should not be too excessive because a slowdown in wind power development permits may also indicate that the market is nearing saturation. Only by gradually sweetening the feed-in tariff rate can policy makers unconditionally confirm whether the wind power market is slowing due to profitability constraints or capacity constraints.

The reason that a real options strategy is well suited to wind power market development stems from the manner in which wind power markets typically evolve. In new wind power markets, developers begin by exploiting the most financially attractive sites first. Typically, coastal sites which are blessed by high quality wind and which lay in closest proximity to a grid connection are developed first (Wizelius, 2007). The wind power market continues to expand as developers exploit all viable sites where revenues earned exceed operating costs plus required rates of return. Eventually, a first stage of saturation is reached wherein the commercially attractive sites have been fully developed leaving only unprofitable sites for future development. At this stage, in the absence of economies of scale or technological developments which reduce project costs, further subsidies become necessary to catalyze market expansion. Increasing the procurement price represents such a subsidy. Once all the commercially attractive sites at this higher level of subsidization are fully developed, the cycle once again slows. In wind power markets around the world, the sequence of development typically begins with coastal sites that boast superior wind quality followed by coastal sites with less superior wind quality, then inland sites and finally offshore sites (DeCarolis and Keith, 2006; Wizelius, 2007). Since wind power markets typically evolve in commercially viable stages, programs which introduce progressively higher feed-in tariffs are the most effective for controlling costs while stimulating activity.

Integration with the current system

Auspiciously, the foundation for an effective feed-in tariff system is already in place in Taiwan. As described earlier, Taipower already offers wind power providers US¢6.06/kWh for wind power generated. Although even executives at the Bureau of Energy who were interviewed for this study admitted that US¢6.06/kWh may now be too low given current market dynamics, establishing this low rate of procurement catalyzed development of the most commercially viable wind power sites. Although it may be true that US¢6.06/kWh is now too low to facilitate inland wind power projects, it is undeniable that Taipower's procurement policy to date has benefited the public by positively contributing to Taipower's bottom line. Assuming that Taipower's cost of producing wind power at its wind farms is at least equal to the cost at which it procurers wind power from private providers (US¢6.06/kWh)[13] and assuming that the average wind turbine provides 8760 h of operational wind power each year at a capacity factor of 25%, wind power contributed at least US$5.6 million to Taipower's gross margin in 2008.[14]

Emerging signs that the most financially attractive wind power sites have been developed indicate that the time might be right for increasing the feed-in tariff. With 281.6 MW of installed wind power capacity and another 467.8 MW of wind power capacity at various stages of planning and development, onshore wind power capacity in Taiwan will reach 75% of the total realizable potential estimated by Taipower. Incentives are needed to encourage offshore developments. Moreover, even officials from the Bureau of Energy have acknowledged that US¢6.06/kWh is too low to encourage development of less profitable inland wind power projects (or more costly offshore projects).[15] Finally, Taiwan's only private wind project developer has taken the extreme measure of publicly denouncing the current feed-in tariff as an impediment to development. It has indicated that unless the current procurement rate changes, it may be forced to consider shifting development plans to other markets.

A hypothetical example which assumes a feed-in tariff increase of US¢9.09/kWh serves to illustrate the financial benefits that such an increase could have for Taipower. If 3000 additional MW of wind power capacity (inland and offshore) could be developed as a substitute for oil-fired power which the government wishes to phase out,[16] the resultant cost savings would amount to US¢6.24/kWh (cost of oil at US¢15.33/kWh − cost of wind at US¢9.09/kWh). Assuming that the new wind power facilities provide 8760 h of annual power generation and a capacity factor of 25%, the addition of 3000 MW of wind power capacity would generate 6.57 billion kWh of electricity each year. At a cost savings of ¢6.24/kWh, the switch would save Taipower US$409,968,000 per year.

Admittedly, increasing the feed-in tariff to US¢9.09/kWh will eventually result in cost increases for procurement of wind power at existing wind power installations. However, this represents a negligible cost given the US$410 million which will be saved by switching from oil to wind power. Even if all existing wind power procurement contracts were renegotiated at the new rate of US¢9.09/kWh, the overall cost increase to Taipower would amount to less than US$19 million. Clearly, absorbing a cost increase of US$19 million for

[11] Based on the following equation: (total installed wind capacity × annual operational hours × capacity factor × cent increase in feed-in tariff, which yields ($10^9 \times 8760 \times 0.25 \times 0.01$).

[12] European feed-in tariff estimates taken from a PowerPoint presentation of Infravest (9 February 2009).

[13] Recently, a television reporter quoted the President of Taipower as informally stating that Taipower's cost for generating wind power was NT$1.68/kWh (US¢5.09/kWh).

[14] Based on the following equation: (total 2008 installed wind capacity in kWh × annual operational hours × capacity factor × (average retail price of energy − average cost of wind power), which yields ((281,000) × 8760 × 0.25 × (0.0697 − 0.0606).

[15] Anonymous interviews with senior officers of the Bureau of Energy May 13, 2009.

[16] In addition to government intentions, it is the contention of this author that current capacity of oil-fired power (3600 MW) is not necessary for supporting peak fluctuations due to the sufficient capacity in hydropower (4513 MW), LNG-fired power (8606 MW), and cogeneration power (7220 MW), which together account for approximately 45% of Taiwan's total power generation capacity.

the prospect of saving US$410 million represents a trade-off that any organization would accept. In reality, it is believed that the current procurement system contractually locks in purchases at the rate of US ¢6.06/kWh for 15 years. Accordingly, in practice, a rate increase will not increase costs associated with existing wind power installations until this contractual period ends.

Policy lessons learned

Scientific and technical studies as strategic tools

For policy makers in general, the Taiwan case study serves as a reminder that scientific and technical studies that are frequently commissioned to guide decision making are rarely objective. We saw how two technical estimates dealing with a common theme (the realizable potential of wind power) differed significantly due to incommensurable subjective assumptions upon which the estimates were based. Consequently, although this is not a new insight for policy experts, it serves as an important reminder that policy evaluation is frequently a continuation of politics by other means (Bovens et al., 2006). For agents of change who are seeking to overcome opposition from vested interests, seeking to master the strategic applications of scientific and technical studies improves one's capacity for persuasion. For policy makers who are seeking transparency in decisions which impact the public, the case reminds us that efforts should be made to explicate the assumptions upon which scientific and technical studies have been carried out.

The Taiwan case also demonstrated how attempts to understand the organizational culture of a given organization can help to shed light on the nature of technical or scientific assumptions it makes to defend its strategic practices. The caveat for public policy makers who are developing policies based on internally generated scientific or technical studies should be obvious. Technical studies which are developed by public organizations may understandably be based on assumptions which are inherently conservative. Therefore, decisions based on these studies may not fully incorporate market reactions to initiatives based on the merits of these studies. Policy makers should endeavor to compare internally generated scientific and technical studies to privately commissioned studies in order to assess the extent to which organizational forces influence objectivity. If policy makers at the Bureau of Energy in Taiwan undertook such an exercise, the disparity between Taipower and Infravest realizable wind potential estimates might have been enough to encourage a more aggressive policy toward wind power development.

Finally, for policy makers in the field of energy, the case serves as a reminder that energy is a highly politicized field in which scientific and technical studies are regularly employed as strategic tools for defending ideological positions. Campaigns of misinformation have been highlighted as one of the most important contributors to public apathy over climate change (Hansen, 2008). In considering the nexus between Taipower's estimate for realizable wind power potential and its suspiciously low data on the price of nuclear power in Taiwan 9 (Table 2), one cannot help but wonder if there are not political influences that taint both data sets. If policy makers are to counter misinformation put forth by entrenched vested interests (i.e. nuclear and fossil fuel advocates and lobbyists), formal communication strategies must be put in place to counter such propaganda. This further implies that policy campaigns for encouraging organizations in the energy industry to modify strategic behavior would benefit from strategic use of scientific and technical studies.

The real options strategy for public policy

The Taiwan case study provided insight into requisite conditions for applying a real options strategy in public policy. Primarily, it is effective in complex, dynamic policy settings where a general policy direction is indicated but existing information is insufficient for supporting the implementation of aggressive policies which are then left to run their course. Other requisite conditions include (1) the policy challenge must be non-critical (i.e. not an emergency response) because a real options strategy assumes that the initial policy will likely be suboptimal, (2) performance of the policy must be measurable on a progressive rather than a dichotomous basis because continual improvement is the goal, and (3) organizational and structural elements need to be malleable enough to support continuous policy improvement. These conditions describe many policy challenges. Consequently, it is a strategic approach that is widely applicable in the policy world.

The Taiwan case study also provided some guidance on conditions which render real options strategies necessary. At some point during the lifespan of a policy, indications begin to emerge (usually from external sources) that the policy is potentially no longer appropriate. Among other reasons, indications of policy mismatch arise due to changing social dynamics, changing market dynamics, changes in ideology, or even the emergence of data which indicate that the current policy may be either ineffective or misguided. In the Taiwan case study, social, commercial, and political changes catalyzed concern that perhaps the conservative wind power potential estimate upon which wind power development policy was predicated is considerably lower than actual realizable wind power potential. The emergent concern merits further attention because if actual realizable wind potential in Taiwan is significantly higher than Taipower projects, a robust wind power development program could substantially contribute to the achievement of desirable strategic objectives (improving domestic energy security, stabilizing energy prices, reducing CO_2 emissions, etc.) and save millions of dollars in costs.

The case also demonstrated that in the presence of dissonance between a current policy position supported by vested interests and affected stakeholders, a real options strategy can mitigate opposition to change by producing tangible results which can be utilized to support a more comprehensive policy design. The history of policy making has proven that it is easier to implement small programs than larger more expensive programs and it is easier to modify existing programs than to initiate new programs (Salamon 2002; Fischer et al., 2006). Therefore, a real options strategy represents a formalized method for operationalizing policy insights which have stood the test of time. On a practical note, implementing a policy based on real options strategy also delivers an added benefit of allowing policy makers to modify policies based on actual experience in order to enhance effectiveness.

In closing, it is insightful to differentiate a real options strategy from social experiments, which are well known in policy circles and exhibit some similar characteristics. A social experiment is similar to a real options strategy in that both attempt to validate policies based on actual performance. In social experiments, researchers segregate a given population into a treatment group and a control group. A policy is then applied to the treatment group and the impact that this policy has on the group is compared to the control group in order to determine the effectiveness of the policy. The main purpose of a social experiment is to determine whether or not applying a policy is superior to the status quo (or another treatment) according to a prescribed set of performance indicators (Cook and Campbell, 1979). A social experiment does not necessarily seek to improve the policy itself. Conversely, a real options strategy does seek continual improvement. The manner in which a real options strategy makes iterative adjustments to policies based on ongoing feedback represents a fundamental difference that distinguishes it from social experiment strategies. However, this difference does not preclude the strategies from being combined. Conceivably, a real options strategy could be implemented in a manner that utilizes social experiments to track the effectiveness of each progressive policy improvement. Although the time-consuming nature of this approach would limit application, combining the two approaches together would induce a degree of scientific rigor to the application of a real options strategy that would not otherwise exist. This perhaps represents a future challenge for enterprising researchers interested in social experiment methodologies.

The expanded use of feed-in tariffs

In renewable energy policy circles, feed-in tariffs are generally promoted as policy tools which can allow fledgling technologies to gain a foothold in an established energy market (Komor, 2004). When employed for achieving such an objective, experience has shown that feed-in tariffs should be gradually decreased over time in order to encourage innovation and cost reduction efforts on the part of parties who are developing the technologies. The feed-in tariff system implemented in Germany in the 1990s and subsequently amended in 2000 to reflect progressive cost improvements in renewable energy exemplifies the effectiveness of feed-in tariffs for supporting emergent technology (Komor, 2004).

The Taiwan case study presents an alternative application of feed-in tariffs. It was asserted in the study that a feed-in tariff system can be aimed at established technologies in order to encourage innovation and reinvigorate market development. When employed for achieving these types of objectives, the feed-in tariff should be raised rather that lowered over time. Initial feed-in tariff rates should be established at levels which are just sufficient to encourage the development of projects in the most commercially viable areas first. As the most economically attractive developments reach saturation point, the feed-in tariff rate should be increased to encourage market players to develop areas which may not have been exploited under the lower tariff rate.

The benefit of conveying strategic intent

Overall, the Taiwan case also reminds us that the concept of *strategic intent* which is well known in strategic management circles also applies to public policy making. Strategic intent can be defined as a conscious attempt by strategists to structurally commit an organization to a clear strategic direction (Hamel and Prahalad, 1989). The value of doing this is that it consolidates understanding of organizational objectives and engenders commitment. For example, when Spanish conquistador Hernán Cortes landed in Veracruz, Mexico in 1519 with the intent of establishing a colonial settlement, he purportedly ordered the demolition of the boats which had carried the settlers. By removing the strategic option of giving up and leaving, he effectively committed the settlers to establishing an effective colony.

Critics of the concept of strategic intent warn that the strategy must be employed cautiously because in competitive environments the act of revealing one's strategy can allow competitors to exploit strategic weaknesses (Bartlett et al., 2003). However, in public policy, the benefits associated with clarifying policy direction far overshadow the threats associated with exposing policy intents to those who may oppose the policy because effective coordination of stakeholders is frequently a requisite for policy success (Salamon, 2002).

In the case of Taiwan, although there has been talk about radically reforming Taiwan's energy markets and President Ma has publicized a political commitment to reduce CO_2 emissions to 50% of 2000 levels by 2050, there is a conspicuous lack of strategic intent to support achievement of such aspirations. If the goal is to encourage the emergence of a carbon-free energy sector, stakeholders must be incentivized to achieve such a goal. For example, new incentives should be devised for Taipower to encourage a prioritization of renewable energy capacity development. Barring the introduction of new incentives, Taipower will continue to do the exemplary job it has done in the past of securing Taiwan's national energy security. Similarly, incentive systems need to be designed to encourage market players to proactively seek out new sites. Admittedly, Taiwan is a nation that faces land constraints which place certain limits on the development of traditional renewable energy programs (i.e. biofuel initiatives, wind farms, applied title technology, etc.). However, if incentives are significant enough, innovation will emerge and solutions will be found to facilitate a transition to more sustainable energy generation technologies.

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