# Extending Green Technology

*The viability of wind power in Argentina*

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As the technology to harness the potential power of wind has developed, the explosive growth of the wind power industry in the last five years has been stunning. A zero emissions energy source, wind power has grown at a rate of over 25% per year for the last five years, a growth rate which implies the doubling of installed capacity approximately every three years (Gil 2005; see figure 1). However, as table 1 shows, the increases in installed capacity have been significantly limited to a handful of European countries and to the United States. This raises the important question, recognizing that the vast majority of installed global wind capacity is in the so-called developed world, is wind power also a viable alternative to fossil fuel for countries in the developing world?[1]

Several characteristics of wind make it particularly attractive. An exceptionally clean resource, exploitation of wind avoids many of the negative externalities associated with electricity generation, with expected benefits to both human health as well as to the environment. Furthermore, substituting wind for burning fossil fuels should lower greenhouse gas emissions, a crucial step in minimizing the risks associated with further climate change. Lastly, wind is available in many regions of the world, and often in areas currently lacking other resources. Not only as a valuable additional resource, but also as a resource which can reduce a country's exposure to commodity price fluctuations and supply constraints, wind is, especially in light of the steadily rising price of oil, an intriguing new development in the global energy arena.

However, the economic viability of extraction is fundamentally limited by the geography of existing wind resources. Furthermore, even sustained, high wind velocity is not sufficient, as evidenced by largely unexploited wind resources in remote regions of

[1] Immediately, the presence of India and China in the top ten list of installed wind capacity suggests that this is not the case. However, as India and China can hardly be considering representative of "average" developing countries, further investigation is warranted.

the developing world. One such example is Argentina, which in 2004 ranked thirtieth in installed wind capacity, in spite of the fact that the Patagonian region of Argentina is widely lauded as highly promising, given its unique combination of low population density, strong and sustained wind velocity and proximity to potential markets.

The “relative isolation” of Patagonian resources emphasizes a crucially important trade-off in the wind industry, between minimizing the perceived visual impacts of wind turbine installation and the distances to markets where the captured resource can be sold. The sustained high velocities, on the other hand, bode well for measures of capacity utilization --a measurement of actual power generation divided by total potential power generation over a given time period--, which in existing Patagonian wind farms have approached 44%, well above the 25-30% range common in the United States and Western Europe where turbines are also employed[2].

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Thus, while most installed capacity is currently found in a limited number of wealthy countries, Argentina provides an interesting case study by which to analyze the viability of wind power in the developing world. To begin with, to what extent is wind available in Argentina? How is wind transformed into electricity, and to what extent has this occurred in Argentina? On a related note, how does one reconcile the abundance of wind in Patagonia with the relative lack of installed capacity? Is this simply the result of the slow transfer of technology, or are there additional barriers (compared to countries with greater installed capacity) which impede the deployment of renewable energy in the

[2] For aggregate data on the efficiency of wind power, see the World Wind Energy Association website, <www.wwea.org>.

developing world in general, and in Argentina in particular? What is limiting the development of the wind power industry in Argentina?

I propose to tackle these questions in two principal sections. First, I will evaluate the progress to date in Argentina, showing that though Argentina has resources which are commercially viable using existing technology, little exploitation has taken place. Second, drawing heavily on the material presented in the preceding section, I will discuss the obstacles inhibiting further growth in the industry, separated as (1) technical/physical, (2) economic or (3) political/institutional, to show that while Argentina (and by extension, countries in the developing world) suffers from similar obstacles as wealthier countries, solutions have been harder to come by to suggest that the problem is not so much additional barriers as it is insufficient policy response. Addressing this point, I will offer seven key policy suggestions. To conclude, I will discuss how the experience of wind power in Argentina is generalizable to other countries in the developing world, to suggest that further expansion of wind power into the developing world is likely justified.

## Part I- Background Information

### *Existing Wind Resources*

A number of authors have identified Argentina as a viable location for wind power generation. Archer and Jacobson (2005), noting that one of the largest barriers to expanding wind power generation is the difficulty in identifying optimal sites, extrapolate 80m wind speeds (the height of modern 1.5 MW turbines) from the 10m measurements more common throughout the world.[3] Tower data from the Kennedy Space Center are

[3] The authors first identify six prototypical curves relating 10m and 80m wind speed, then apply a Least Squares methodology to determine which curve offers the "best fit" between predicted and actual wind

then used to validate the estimations. Arguing on a global scale, the authors assert that using existing technology and focusing only on sites with mean annual wind speeds above 6.9 m/s, if only 20% of the existing energy is captured, it would satisfy over 100% of the world's energy demands. Furthermore, this quantity exceeds total global electricity needs by over seven times, a finding which suggests that the strong recent growth of the wind industry can be maintained, so long as appropriate new sites are identified. By providing a mechanism to use surface wind data to generate approximations for wind at the height of modern turbines, the authors greatly expand the potential area for consideration, and increase the accuracy of forecast wind data.

In passing, the authors note that of the few suitable locations in South America, most promising are (1) the southern-most tip of Argentina and Chile and (2) the coastal area of Argentine Patagonia between Bahia Blanca and Peninsula Valdez (6). The authors also note that as the Coverage Index (measure of the percentage of land with available data) is low, their results are not necessarily exhaustive. While this certainly does not invalidate the sites they have identified as optimal, other sites for which the data was not available--the authors state that all governments and agencies were *not* equally cooperative with foreign academics/analysts—could, and likely do, also exist.

Another group of authors, focusing explicitly on Argentina, combine an analysis both of wind potential and of existing infrastructure to determine the most economically viable sites. Using long-term meteorological data and cross-checking with existing records from wind farms, Moennich, *et al.*, define the area most suitable for exploitation, shown as the red hatched region in figure 2. It should be noted that as these authors also

speed for each specific measurement site. Their specific mathematical and geophysical methods are beyond the scope of this paper; for more information, see Archer and Jacobson (2005).

focus on producing hydrogen with wind energy, their results understandably diverge somewhat with those of Archer and Jacobson. However, Moennich, *et al.*, utilize data unavailable to Archer and Jacobson, and generate a more detailed map of existing wind resources in Argentina.

Though both sets of authors agree that the Argentina Patagonia is generally suitable for wind extraction, Archer and Jacobson argue that the 90% increase in wind speed by moving directly off-shore makes a powerful case against onshore wind parks.[4] These authors seem to ignore the practical difficulties associated with offshore wind parks, letting the higher wind speeds automatically offset the higher costs. Though perhaps true in other regions, the sustained high velocity of winds in the Argentine Patagonia minimizes the *marginal gain* of moving offshore. This claim is further substantiated by the absence of offshore wind farms both in the actual as well as in the proposed projects, to be described subsequently.

Overall, Argentina is relatively well endowed with wind resources, though the best resources are concentrated in the Patagonian states of Santa Cruz and Chubut. As Table 2 shows (page 13), though there are a limited number of projects currently active, the average wind speeds at most sites are quite high. While wind speeds greater than 6.9m/s are generally recognized as sufficient for wind power generation, the wind farms in Santa Cruz and Chubut, for example, boast average speeds of near 11m/s (Gil 2005). The higher productivity of wind farms in Argentina (Brendstrup 2005) is primarily a consequence of the sustained strength of Patagonian wind, whereas the performance of the farms in the Buenos Aires province is less exceptional.

[4] Examples of offshore wind farms include the Horns Reef project in Denmark and the proposed project off the coast of Cape Cod. For more information, see Archer and Jacobson (2005) and the AWEA website (www.awea.org).

Though Argentina has abundant wind in Patagonia, wind generation currently makes up an insignificant portion of the national energy supply. Figure 3, from the International Energy Association, show the tiny proportion of electricity provided by wind power. As will be detailed in subsequent sections, the current insignificance of wind on a national scale in Argentina is a result of the fact that not a single large-scale wind farm in Patagonia is connected to the national grid (Giumelli 2005). Furthermore, as figure 3 might suggest, Argentina has a great abundance of natural gas reserves. Although far from ideal from an environmental perspective, electricity production from burning natural gas currently makes economic sense, and minimizes many incentives for expanding wind power. Nevertheless, reliance on nonrenewable resources such as natural gas by definition cannot continue forever, and the earlier a country begins to diversify its energy portfolio, the easier the transition is likely to be.

Somewhat strangely, wind is abundant in Argentina, while electricity generated by wind is not. Before discussing the specific projects currently underway in Argentina, however, it is helpful to understand how the profitability of the industry has changed with recent technological changes.

*Economics of Wind Energy*

The advances in wind turbine technology have caused the price per kW of wind power generation to fall over 80% in the last 20 years (AWEA.org). The market value of 5 cents/kW, however, fails to capture the total economic benefits of wind energy, for example, the avoided costs associated with rising fossil fuel prices and the negative externalities of using environmentally damaging substances such as fossil fuels. Furthermore, wind energy's substantial environmental benefits, though difficult to monetize, increase the attractiveness of wind power. Manwell, *et al.*, focusing on the Netherlands for 1995-2010, show that the total avoided costs of wind energy are on the order of 5 to 7 cents/kWh, included as figure 4 (2002). Though it is difficult to generalize the results of the Netherlands to Argentina, particularly the value of the monetarized environmental benefits, the limited use of wind energy in the developing world makes the corresponding calculations for developing world economies difficult to find. The cost range is included solely as an indication of the order of magnitude of the total avoided costs of wind energy, while recognizing that the actual value in Argentina may differ substantially. For example, while the regulations in Argentina aren't nearly as stringent as in the Netherlands, the health benefits of avoided pollution could conceivable be far larger, due to more pollution-intensive electricity generation characteristic of Argentina. On the other hand, the lower wages in Argentina imply a lower opportunity cost associated with lost labor hours. Nevertheless, it is likely that the orders of magnitude of the avoided costs of wind in Argentina and the Netherlands are similar.

Though valuable in many respects, the analysis presented by Manwell, *et al.*, focuses primarily on wind energy in wealthier countries. In the Netherlands, for example, the authors assume that any wind plant can be readily connected to a fully integrated and well-maintained national grid. Not necessarily the case in all countries, this model must be adapted to the practical reality of the wind industry in the developing world. Brendstrup (2005) discusses similar data for Argentina, and makes some interesting conclusions. Asserting that the nature of the wind in Patagonia makes wind power generation more efficient, the author shows that the cost per kWh of wind energy is actually lower in Argentina than in Spain, Germany or the USA. This graph is included as figure 5, though it gives only the cost of generation and not of transport. Perhaps understandably, transport costs are a crucial dimension of the analysis of wind energy in Argentina, like much of the developing world. For even in areas where electricity transmission infrastructure is present, poor maintenance and extremely large distances often imply an unacceptable level of “line loss,” the percentage of electricity lost in transmission. In Patagonia, this is further complicated by the lack of high-tension lines connecting the wind parks to the national market.

Thus one of the greatest challenges facing wind power proponents in Argentina is finding a suitable vector for transmitting the captured wind energy, especially a clean vector which doesn’t defeat the environmental benefits of wind energy.[5] Though the more obvious conclusion is to extend transmission infrastructure, the progress of which will be documented subsequently, Moennich, *et al*., offer an ambitious alternative. And though there are important technical challenges associated with its practical use, liquid hydrogen is emerging as a promising potential vector.

The authors analyze the feasibility of large-scale liquid hydrogen production in Argentina, though their final analysis is highly contingent on assumptions of future prices (of hydrogen and traditional fossil fuels), of the efficiency of the electrolysis and the liquefaction process and of the costs of wind power generation. Their language, however, resembles that of Kathleen Bader, chair of a subsidiary of Cargill, Inc., who recently stated that though early adopters of a recently developed product were motivated by environmental concerns, fossil fuel price fluctuations had caused their product to become competitive in niche markets where it previously was not (Deutsch 2005).

[5] Car batteries are often used in rural developing countries because they are readily available and familiar. Not meant to be drained and recharged, car batteries (even with strict maintenance) are ill-suited for this use and quickly wear out. Disposal carries the risk of environmental contamination (lead, for example).

Using wind-generated electricity to split water molecules and yield hydrogen and oxygen gas, the latter of which can either be captured or released, the process only requires a source of freshwater and of persistent wind. The hydrogen is condensed, to be transported as a liquid via pipelines and barges to target markets. Their conclusion, that the production of liquid hydrogen is currently not competitive with traditional fossil fuels, but may be economically feasible in the future, has been used to justify building an experimental hydrogen plant in Argentina. In the immediate future, the effect of this experimental plant is to provide the residents of the town of Pico Truncado with a fuel source other than fossil fuel derivatives, which, particularly when used inefficiently in buildings, have been shown to be a significant health hazard (Khennas 2002). Hypothesized extensions of the use of hydrogen range from the ambitious -- conversion of the bus fleet of Buenos Aires, a notorious source of the city's air pollution, to hydrogen--, to the decidedly practical local use described earlier. While it is as unlikely that hydrogen exports will become a large source of income for the province as it is that they will for the country, this groundbreaking research offers an exciting glimpse into a possible future of alternative energy.

*Current Projects*

The current use of wind power can be split into two categories. Small scale wind systems for local use in isolated rural communities comprise the first category, while larger farms for use beyond the local region comprise the second. Though the former are less relevant for commercial considerations and certainly less attractive for the kind of multinational corporation investment that has driven the expansion of the wind industry in the past, ignoring small scale wind systems minimizes the developmental benefits of extending electricity to rural population.

When electricity infrastructure doesn't extend to a rural area, residents are forced to find alternative sources of electricity. Common alternatives include diesel fuel or even car batteries; however, often energy needs simply go unsatisfied. Thus, the potential demand for such systems is generally assumed to be quite high. The human development motivation for providing rural populations with electricity is largely self-explanatory; unlike other modern "privileges," access to a refrigerator, for example, has undeniably positive effects on human health.

Koluel Kaike, a small town of 500 residents and located 23 kilometers from Pico Truncado, is an ambitious pilot project to satisfy the needs of an entire town strictly with renewable energy. Though in its infancy, the project aims to have achieved the transition by 2008. Chosen because of its proximity to the hydrogen plant in Pico Truncado, the United Nations selected Koluel Kaike as one of five sites in the world where it would support 100% renewable energy projects. Admittedly, this project currently falls near the extreme end of the spectrum of renewable energy use. As the availability of fossil fuels continues to decrease and the consequences of emitting greenhouse gases becomes more tangible, however, it is likely that more and more communities, and not exclusively those with limited access to traditional fuel sources, will turn to renewable energy such as wind.

Not all projects serving isolated rural communities need be so ambitious, either. Khennas, *et al.*, outline a rural battery charging system, relying on a single turbine that members of a community can plug into to charge car batteries. Currently in use in locations as diverse as Peru and Sri Lanka, wind provides a more environmentally benign source of electricity than diesel generators. Additionally, wind eliminates the supply problems associated with diesel, and is cheaper than photovoltaic cells (Khennas, *et al.* 2002).

Alternatively, wind farms can be used as a substitute for traditional fuels in the provision of electricity. In Argentina, the town of Pico Truncado currently derives one third of its energy needs from wind farms. Though the town only has a population of 15,000, the policy inertia associated with changing the status quo is still significant. By switching from a reliance on fossil fuels, the town has both increased the sustainability of its electricity base as well as provided its citizen with significant health benefits. The avoided costs of not using fossil fuels can also be a significant factor motivating the switch to wind power. Quite simply Pico Truncado is, absent further investment in transmission infrastructure, the future of wind energy in Argentina. A successful example of how to exploit wind, the town offers a workable model[6] for other similarly sized communities looking to substitute away from traditional fuel source.

Another option is to connect wind farms to the national grid to provide electricity both to the domestic market and potentially for export. Currently the most commercially important manifestation of wind power, connecting farms to the grid has proven difficult in Argentina. Though several farms in the Buenos Aires province are connected to the national grid, these farms are hardly the optimal sites for electricity production. As previously noted, the ideal, strong winds are much farther south.

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[6] In fact, the Patagonian town of Comodoro Rivadavia, population closer to 100,000, derives a significant portion of its electricity from wind power, and followed the example of Pico Truncado.

The province of Santa Cruz, meanwhile, has recently singed a contract to build a wind farm of 34 1.5MW turbines and to pay, in conjunction with the federal government as committed in the *Plan Energética 2004-2008,* for the extension of high-tension lines to the region, connecting this park with the national grid. As work on both the wind park as well as the transmission infrastructure continues, it becomes increasingly likely that Argentina may begin to expand the contribution of wind in its national energy portfolio.

As table 2 shows, the few existing wind farms in Argentina perform as would be expected. The farms in the province of Buenos Aires are rather unexceptional, both in terms of their extent and of their efficiency. As the parks move south and the wind speeds increase, however, the efficiency and profitability of wind power increases. The capacity utilization readings of 40% are well above those generally found in other parts of the world, so the natural question follows, why hasn't there been more development of the wind industry in Argentina?

*Table 2*

| **Province** | **Project** | **Number of Turbines** | **Installed Capacity in kW, 2004** | **Actual Generation in MW, 2004** | **Factor Utilization** | **Average Wind Velocity (m/s)** |
|---|---|---|---|---|---|---|
| Buenos Aires | Claromeco | 1 | 750 | 1,873 | 28.40% | 7.3 |
| Buenos Aires | Darregueira | 1 | 750 | 1,306 | 19.80% | 7.3 |
| Buenos Aires | Mayor Buratovich | 2 | 1,200 | 0 | 0.00% | 7.4 |
| Buenos Aires | Punta Alta – Centenario | 3 | 1,800 | 4,550 | 28.80% | 7.8 |
| Buenos Aires | Punta Alta – Pehuen | 1 | 400 | 639 | 18.20% | 7.2 |
| Buenos Aires | Tandil – Cretal | 2 | 800 | 1,700 | 24.20% | 7.3 |
| Chubut | Comodoro Rivadavia - Antonio Moran | 24 | 16,560 | 50,381 | 34.60% | 11.2 |
| Chubut | Comodoro Rivadavia - Pecorsa - Cerro Arenales | 2 | 500 | 1,311 | 29.90% | 11.2 |
| Chubut | Rada Tilly | 1 | 400 | 1,423 | 40.50% | 10.8 |
| La Pampa | General Acha | 2 | 1,800 | 3,353 | 21.20% | 7.2 |
| Neuquen | Cutral Co. (COPELCO) – Meulen | 1 | 400 | 686 | 19.50% | 9 |
| Santa Cruz | Pico Truncado - Jorge Romanutti | 2 | 1,200 | 5,224 | 49.60% | 11.4 |
| | **Total in Argentina** | **42** | **26560** | | | |

Source: Gil 2005.

## Remaining Challenges and Policy Solutions

Having established in the previous section that Argentina has ample wind resources that are commercially viable using existing technology, one must make sense of the fact that considerable development of the wind industry has *not* been accomplished. As in all markets, there are barriers associated with changing the status quo, and the energy market in Argentina is no different. For simplicity's sake, the principal barriers have been divided into three sections. First, the primary technical/physical barrier is the extension of transmission infrastructure, as domestic turbine production, which can significantly lower the total cost of wind, has largely been achieved (Brendstrup 2005). The second set of barriers is economic, and relate to the high relative cost of alternative energy. Lastly, institutional/political barriers address non-marketplace concerns associated with the interactions between and within the public and private sectors. Seven key policy suggestions conclude the section.

*Technical/Physical*

Moving towards the practical issue of extending the national electricity infrastructure (the "grid"), one encounters that particularly stubborn of environmental issues, the common good. Though in many ways we have come very far in understanding the dilemmas posed by Hardin in 1968, "the inexorable succession of generations" insures that tragedies of the commons will never entirely disappear.

Argentina's history of populist policies has given rise to an interesting manifestation of the free-rider problem. Following the privatization of the electricity sector, Argentina enacted a ban on vertical integration. However, while the marketing and generation of electricity were privatized, the transmission was sold to a state-run enterprise. Whatever intentions of fostering competition led to the adoption of the ban, the reality has been serious problems in financing new investments. Due to a law which dictates that all transmission lines must be open-access, utility companies have little incentive to pay for the expansion, knowing that their competitors will have the legal right to use the line once it is constructed.[7] Future users are also expected to contribute to the construction of lines connecting their communities to the national grid, but each potential user faces the same calculus. Artana, *et al.*, rightfully note that "this creates an obvious incentive for not revealing true preferences if charges for investments are based on the revealed preference of each [actor]" (1998). Hiding preferences hints at the kind of strategic bargaining that confounds elegant Coasian solutions to environmental problems, a point which I will elaborate on in subsequent paragraphs.

When there are fewer participants, cooperative rules have been developed to finance new investments. Commonly used in Scandinavia, these agreements overcome temptations to free-ride by limiting the number of actors, and making each actor accountable to all others. This appears to be the strategy adopted with the construction of the wind park to be connected with the national grid in Santa Cruz. The provincial government, in conjunction with the publicly owned company INVAP, has agreed to finance the expansion. Though economic efficiency certainly would dictate that the future beneficiaries should participate in the financing of electrical infrastructure extension, this has not been the case.

[7] This point is especially relevant for wind energy. As the individual contribution of a particular wind farm is likely to be small relative to the minimum load feasible to warrant the expansion of transmission lines, investments in wind face an additional barrier compared those in more traditional energy sources.

The poor definition of property rights has in general caused investments to stagnate. Some have turned to drafting new legislation to govern private agreements which would assure preferential access to those with the resources to pay upfront for the construction of the line, though this legislation is actively opposed by the smaller firms and rural constituencies it seeks to punish (Artana, *et al*.). Certainly an alternate approach would be to simply allot property rights arbitrarily and let the individual actors bargain to a mutually beneficial outcome, though the presence of many actors, basing their strategic bargaining on imperfect information, suggests that the neutrality predicted by Coase is unlikely.

*Economic Barriers*

The economic challenges associated with expanding wind energy are considerable, and relate to the uneven competition between new and existing technology. Especially in the energy market, the most obvious influences on market prices are direct and indirect subsidies. Neuhoff contends that while OECD countries spent on the order of US$20 billion on energy subsidies in 2002 alone, the subsidies awarded by individual developing countries are usually relatively greater. Though cheap domestic rates are politically salient, and though they are sold as measures to make electricity more affordable to the poverty-stricken masses of the developing world, subsidies rarely achieve this goal. Usually of greatest benefit to the well-off households that consume the most electricity, subsidies also shield electricity producers from the increased competition of alternative energy, keeping prices unnecessarily high (Neuhoff 2005).

Encouragingly, Argentina has begun to subsidize the production of wind electricity. Brendstrup (2005) shows that the incentive currently offered by the federal government is 0.010 peso/kWh, compared to a cost (excluding transport) of 0.066 pesos/kWh. Additionally some provinces offer an additional subsidy, which in the case of Santa Cruz is an additional 0.005 pesos/kWh. This initial level of subsidies doesn't begin, however, to level the playing field between wind energy and energy derived from burning fossil fuels (Gil 2005).

Another source of uneven competition is the failure of conventional energy sources to internalize environmental impacts. Generally, environmental regulations take the form of "command and control" policies, under which emissions below regulation levels are not penalized. Firms are, in effect, encouraged to emit freely at lower levels of pollution, unexposed to the costs of the initial environmental damage. These un-priced externalities are an indirect subsidy of existing energy sources, especially as newer technologies are likely subjected to a more thorough analysis of environmental costs than their preexisting competition.

Neuhoff also points to certain characteristics of the energy transmission network which make it ideal for centralized power plants, and prejudicial against renewable energy. For example, while decentralized wind generators can reduce peak loads on the distribution system at times of maximum usage, network tariffs do not generally reward this kind of service. Furthermore, the inflexible design of the electricity market suggests that wind energy, when it produces power intermittently[8], will not necessarily do so additional power is needed. In light of the fact that most power plants can quickly change their output within the time frame needed to accurately predict the output of wind

[8] The government's classification of wind power as non-predictable prohibits governments from accepting contracts for power payment, though a trade group has proposed legislation to allow power purchase agreements or PPAs. These are effectively long-term supply contracts between farms and individual consumers, and are backed up by hydroelectric generators to insure consistent electricity availability. Spinadel describes PPAs in greater detail in Siteur (2005).

systems, wind generated electricity currently produces less revenue than it would in a more efficiently designed market (Neuhoff 2005).[9]

Turning to financing costs, conservative risk assessments of capital-intensive new technologies further depress the potential for wind power. Furthermore, short-term contracting is common in electricity markets, a practice which can reinforce cyclical investment patterns without substantially contributing to the kind of long-term investments necessary for the research and development of new technologies (Neuhoff 2005). Thus, in addition to the policy inertia to be discussed subsequently, there is a kind of financing inertia against expanding wind power generation.

*Political/Institutional*

One of the most important obstacles when trying to formulate forward-thinking policy is the short-term focus imposed by the democratic political cycle. As politicians are generally most concerned with making sure they are reelected, promoting projects and investments where the return on investment becomes significant after the next round of elections are less likely to win support. Undesirable on a number of levels, short-sighted policy making robs society of potential increases in productive capacity whenever the most promising investments have a payoff structure of longer than a few years.

In Argentina, this institutional short-sightedness was worsened by the economic and political crisis of 2001-2002. Even after years of impressive growth, many important economic measures have yet to return to pre-crisis levels. One important example is the poverty index, which after the devaluation, and the subsequent recession, peaked near

[9] Operators of traditional power plants also have an incentive not to cooperate with wind utility operators, as doing so implies losing revenue to their competitors.

50%. Such a high proportion of citizens living in poverty severely limits the political viability of investing in alternative energy sources such as wind power that promise benefits to be paid in the future. Furthermore, ongoing negotiations with the IMF have done little to limit the fears of international investors that Argentina remains an insecure investment location.[10]

It is not only the short-sighted policy making which has dampened investment in wind energy in Argentina. The general policy inertia affects even those politicians with a long-term vision. Insofar as the policy inertia stems from risk-averse politicians, and their reluctance to change the status quo, this inertia is a logical potential consequence. Furthermore, Argentina's proven vast reserves of natural gas make proposals for alternative energy especially vulnerable to political criticism, arguing that there are more important places to spend the money today, since the natural gas reserves will still be around tomorrow. Though this argument ignores the effect of burning natural gas on global climate change, it is unsurprising that domestic politicians try to "free-ride" on the global commitment to cut greenhouse gases, particularly given the current popular sentiment against the United Sates and that country's leading role in global carbon emissions.

Policy inertia is a problem well beyond Argentina, however. Neuhoff identifies several characteristics of successful wind turbine deployment in Denmark, including long-term thinking, local community involvement, benefits to incumbent energy companies, public and private research and development support, and government

[10] For example, a plan developed prior to the crisis proposed installing 3,000 MW of capacity in Patagonia between 2000 and 2010 (Goodman 2001); this plan was effectively abandoned for three years, and though funds have reemerged, there is currently little support for such ambitious projects.

support (2005). Of these five, no single strategy stands out as infeasible in the developing world, as even the availability of financial R&D support is clearly not a tight constraint.

Lastly, wind power often generates objects due to its perceived visual impact. These "NIMBY" objections often get considerable attention in the media, as a human-interest story that is easy to relate to. Certainly the case in the United States in general, and in Vermont in particular, Braunholtz suggests that the fear of perceived visual impact is usually much greater than the reality. For example, he cites a 2003 survey in Scotland among people living near large wind farms. 82 per cent of respondents supported an increased in wind power generation, while fully 54 per cent supported additional turbines at the nearest wind farm (2003).

In Argentina, the proposed sites for extensive wind farming are in isolated expanses of largely uninhabited land. Even in the scenarios calling for the largest usage of wind power, for example a feasibility study of wind generated hydrogen, the authors determine that achieving their goal of 250TWh/year of liquid hydrogen could feasibly be accomplished, by dedicating an area of 32,000 $km^2$ to wind turbines. Though this would cover over 13% of the entire province of Santa Cruz (or an area roughly equivalent to the state of Maryland), the very low population density of the region suggests that political opposition would be minor (Moennich 2004). On a smaller scale, Spinadel argues that using only 1,000 square kilometers in the Santa Cruz province, an installed capacity of 10GW in windmills would produce the energetic equivalent of 68,000 barrels of petroleum daily. Furthermore, he suggests that such a scheme would be profitable whenever the price of a barrel is greater than US$40 (Urien 2005).

*Seven Key Policy Suggestions*

Recognizing the remaining obstacles, a few key policy changes could easily stimulate the development of the wind industry in Argentina. Many of these policy suggestions are inspired by the list developed by Khennas, et al., (2003), though they have been adapted to fit the necessities of Argentina and various scales of wind power generation where appropriate.

(1) Foremost is the need for more comprehensive and freely available data, taking the form of meteorological data collection confirmed by the operational data of generators currently in use. By opening access to this information, interested firms can make more informed investment decisions and increase the likelihood of success. Given the positive assessments of those with access to the data, increasing the international exposure of the Argentine wind industry bodes well for further development.

(2) Certainly, any policy which encourages research and development of locally appropriate technology would be helpful. The Experimental Hydrogen Plant of Pico Truncado is a good example fitting technology to local needs. Similarly, the local use project of Koluel Kaike is adapting small-scale wind turbines to a very specific set of geographic conditions. If performed locally, such a policy would also encourage “ownership” of projects by communities and potentially create knowledgeable locals to maintain infrastructure.

(3) Legislation which allows small wind generators to enter the grid and sell back excess electricity would provide an additional incentive for individuals currently isolated from, but expecting to be connected to, the national grid at some time in the future. For

this to be feasible, household electrical standards (for wiring and equipment) would need to be publicized and compliance encouraged.

(4) In a more general sense, the government could encourage renewable energy investment through a variety of financial instruments. Tax breaks, grants and favorable loans provide incentives for investment; these instruments could be applied to renewable energy or revoked (in some form) from traditional, pollution electricity-generating industries. Recognizing the difficult politics involved with taking away long-standing subsidies, it is more feasible to advocate extending preferential treatment to renewable resource industries.

(5) Policies need not be so politically demanding. Simply supporting the development of trade associations facilitates the transfer of information and technology among pertinent actors. The Argentine Wind Energy Association is a promising sign in this respect.[11]

(6) By simply increasing awareness of wind power domestically, the government can create interest for the burgeoning industry. The effect of a well-crafted media campaign should not be underestimated. Framing the domestic wind industry as a form of independence and protection from the volatility of the international markets would likely resonate with the Argentine public, particularly given the effects of the macroeconomic shocks in recent collective memory.

(7) Addressing the technical problem of extending transmission lines to the most economically viable parks in the Patagonian region, the government should offer support for collective investment agreements. By doing so, the government can capitalize on the

[11] See their website, www.argentinaeolica.com.ar

political benefits of increased electricity availability without having to absorb the costs unilaterally.

## Conclusions

Though Argentina has proven wind reserves which are commercially viable using existing technology, significant barriers have prevented the widespread exploitation of this renewable resource. Looking beyond Argentina to the initial hypothesis that wind power may be inherently unviable in the developing world, the results are understandably inconclusive in the general case. The economic barriers, for example, seem unlikely to differ significantly between the developing and the developed world. The noted difference in levels of subsidies aside, it seems reasonable that the same policies which leveled the competition between renewable energy in Germany and Spain may work in less developed regions. Similarly, there is little reason to believe contention that politicians are more risk averse in the developing world, and as suggested by the study in Scotland, NIMBY concerns seem to be relatively insignificant after wind turbines have been installed.

However, while political and economic barriers seem relatively comparable between developing and developed countries, the same cannot be said of technical/physical barriers. To begin with, developing countries are much more likely to have geographic regions which are remote and inaccessible due to lack of infrastructure. Indeed, it seems likely that much like the case with Argentina, the physical difficulties of bringing a distant resource to the market are more difficult to overcome in the developing world.

Nevertheless, it is still reasonable to assume that where there is a market for a product, someone will find a way to sell it. The costs of emitting carbon are only going to increase as the world comes to terms with climate change, and contrary to what the Environmental Kuznets Curve might suggest, some developing countries have also taken a leading role in reducing our global tolerance of greenhouse gas emissions. So whether wind becomes the primary clean energy input for the massive future generation of hydrogen or simply helps to decentralize the energy matrix of countries, I expect the industry to maintain its strong growth for years to come by increasing its penetration into markets in the developing world, as well as by expanding into markets in the developing world.

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