"PRODUCTIVE VALUE" AND "CONSUMPTION VALUE" OF WIND-ENERGY

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A consumer entering a store to purchase a briefcase is confronted with a range of models and a wide range of prices. Two briefcases having the same size and approximately the same design can have widely different prices although they fulfill the productive function of transporting papers, laptops and other utensils equally well. Having similar designs, they arrange contents in a way that suits the user, and being equally durable, their cost of use, once purchased, is the same. Yet, some consumers purchase the low cost briefcase made of synthetic leather, others the high cost model made of high quality leather because it looks good and smells nicely Some consumers like the quality aspect so much that they are willing to pay the extra price for it. Thus, even though the "*productive value*" of the two briefcases is the same, the "*consumption value*" is not.[1]

Public discussions on targets for renewable energy policy tend to be sterile because proponents and opponents of ambitious targets for the penetration of renewable energy technologies (RETs) fail to make a clear distinction between the *productive value* and the *consumption value* of renewable energy. The "production value" of RET-generated power refers to its value seen from the *supply side of power generation*. The "consumption value" of RET-generated power refers to the premium payments per kWh, which a significant minority of consumers and Governments are willing to pay for the intrinsic value of electricity produced by a RET for being a "clean" and "sustainable" source of power generation. It is the value of RET-generated power as seen from the *demand side for power generation*. Both sides in the discussion agree that one compares "apples and oranges" in power supply when comparing the value of a kWh from RET with a khW from a thermal power plant. Yet, typically, neither side is consistent in keeping the two levels separate.

The "productive value" of power supply to the grid

The term "*productive value*" refers to the specific value of power supply from individual thermal power plants and windfarms *within the production function of power for the interconnected grid*. The specific value is identified by modeling the optimal power system expansion plan. The plan defines the least cost portfolio of power technologies, which can cover the forecast future demand at the required quality – in terms of reliability, loss-of-load probability, environmental performance, security of supply– defined by the regulatory authority. The "productive value" of power supply from a new power technology is identified by modeling the difference in the expansion plan with and without a specified percentage of supply coming from this technology. Hence, the "productive value of windfarm power" is equal to the *saved* (or *avoided) costs in thermal power generation* that result from phasing in wind energy as a new source of power generation.

When a study does not have access to results from advanced power planning models that have calculated the avoided costs in the power system, use must be made of "rules of thumb" estimates. The contentious issues in the rule of thumb estimates concern (i) the capacity value of windfarm capacity; (ii) the increase in the costs of balancing power from introducing intermittent power generation, (iii) the economic value of the external costs of environmental damages imposed by

[1] In fact, if the person purchasing the briefcase is a management consultant or a banker, he may justifiably claim that the productive value of the more elegant and expensive look is higher, being part of the "branding" used to justify high fee rates in his/her business.

coal fired power plants and by windfarms, and (iv) the economic value of the price certainty of RE-supply versus the market risk and potential macro-economic damage imposed by fluctuating prices of fossil fuels on the international market.

1. The interconnected power system must have sufficient *reserve capacity* to cover the demand for peak power when units are hit by unscheduled production stops. The cost of "firm" capacity is part of the average kWh-cost of production of thermal power. The "*capacity value*" of wind-energy refers to the amount of thermal power capacity that can be saved in an optimal expansion plan per MW of installed or planned windfarm capacity. The ability of windfarm capacity to reduce investments in thermal power capacity, whilst keeping the loss of load probability constant, is debatable. Some power planners claim that it is close to zero: when windfarms become part of power supply, the need for installed thermal power capacity is not affected, the thermal power system saves energy only. The claim underestimates the objective contribution of wind energy to the reduction in the loss of load probability, as shown in power planning models (such as WASP 4) that are capable of modeling the capacity value of stochastic sources of power supply. When no power system simulation studies have been done to yield a modeled estimate of the capacity factor, a "rule-of-thumb"-formula can be used. A very conservative estimate is that the "*capacity credit*" [2] of wind energy is "*60% of the capacity factor of the windfarm"*, meaning that 1 MW capacity of a windfarm with a capacity factor of 40% replaces 0.24 MW of thermal power in the power expansion plan. Investigations in the US seem to indicate that using 100% of the capacity factor during the 1000 hours of system peak demand during a year gives a good estimate. [3]

2. The phasing in of intermittent wind energy in real-time power scheduling imposes a requirement for additional *balancing power*, and thus, increases the payments for balancing power.[4]

3. The economic value of the *environmental benefits from reduced SO_2 and SPM (solid particle matter) emissions*. The negative cost of the environmental impacts of wind farms have to be deducted from these. The most import negative impacts are the *visual impact of windfarms on the landscape* and the *impact on birds*. In general, these impacts are minor. There have been problems at a few sites in the world with rather significant killings of birds and bats. There have also been examples of local resistance to the setting up of windfarms. But, overall, surveys tend to show that the population living in the vicinity of windfarms has a more positive attitude to windfarms than persons who do not, and surveys do not show a negative impact on real estate prices in the local area.

4. *Fluctuating fuel prices impose macro-economic shocks to the economy*, which lead to losses of GDP compared to a situation with better price stability. The macroeconomic damage of fluctuating fuel prices can be internalized by adding a risk premium to the cost of production of conventional power plants. A lower discount rate is used to deflate the cost of fuel in the

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[2] Definition: The capacity value of a windfarm officially accepted by the regulatory authorities and the system operator.
3 Michael R. Milligan: "Modeling Utility-Scale Wind Power Plants. Part 2: Capacity Credit", NREL, 2002
[4] For cost estimates, please refer to David Millborrow: "The real costs of integrating wind energy" in Windpower Monthly, Volume 20, February 2004.

annual costs of O&M.[5] Alternatively, using CAPM-theory, a portfolio-value of reduced production price uncertainty from including wind energy in the generation mix can be calculated. The portfolio value is not just a macro-economic issue; it is also a micro-economic phenomenon: in a free power market, a generation mix with a lower risk of fluctuations in the cost of production has a higher financial value than the alternative mix.

The "consumption value" of "green power"

The term "*consumption value*" – alternatively called "green electricity value" - of power refers to the premiums consumers are willing to pay for a kWh of electricity generated by a "clean technology", when confronted with a portfolio of choices between power from conventional thermal energy and renewable energy technologies. The kWhs delivered by thermal power generators and RE-based generators through the grid have the same "productive value" for final consumers.[6] Yet, some consumers are willing to pay extra for *quality attributes of power that are not included in the traditional economic value estimates for power supply*. The political catchword for these is "sustainable consumption". Due to the existence of a higher willingness-to-pay for "green electricity", the optimal penetration for power supply from windfarms, therefore, cannot be established merely by comparing the cost of production per kWh of windenergy with the avoided economic cost per kWh of conventional thermal power.

The consumption value of RET-generated power is equal to the average premium that consumers are willing to pay for "green electricity" on top of the market price for thermal power.

The existence of a "consumption value"-driven niche demand for renewable energy on the power market is served by power retailers who market "*green electricity*" to consumers. The "*economic value*" of green-power supply, sold on a free market, is equal to the price green consumers are willing to pay. The green price is much higher than the "avoided cost of conventional power generation" (unless very high estimates are made of the environmental cost of thermal power).

The marketing of green power, however, is confronted with a barrier problem. Market surveys for green electricity in OECD countries often report that *30-40% of consumers are willing to pay extra for green electricity. Yet, when asked to sign a contract for a green electricity purchase, typically only 1-2% of total consumers sign up*. The difference between the ex ante and ex post figures for green demand is too large to be explained by a free "feeling good" effect in a survey where respondents are not faced with a purchasing commitment. A major explanation for the difference is that a large majority of potential green consumers are willing to pay extra, but only if everybody else pays as well.[7] Thus, these consumers would prefer a penetration level for renewable energy, which is larger than the free "green electricity" market; yet, their potential demand does not show

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[5] See S. Auwerbuch and N. Berger, "Energy Diversity and Security in the EU: A Mean-Variance Portfolio Analysis", IEA, March 2003

[6] Also in this case there are exceptions: some firms buy "green power" because of the image value in their strategic positioning on the consumer market.

[7] With caution, the difference between the two "green consumers" can be explained with reference to the distinction in normative ethics between *teleological* or *consequentialist* attitudes (actions are judged by their consequences "does it help if I turn green if the others with their consumption continue to pollute?") and *deontological* (actions are judged by their conformance to a principle ("it is not right to follow a non-sustainable lifestyle").

up on the free power market.[8] The conclusion is that the free market for green electricity does not reveal the economically optimal penetration of RE-supply.

The barrier problem of an unsatisfied notional demand for green power, which is larger than the free market demand for green power, is solved through *political intervention*. Discussions on national energy policy lead to the adoption of a *policy target for the penetration of RE*, such as the 10,000 GWh-target in South Africa for the year 2012, which creates a market for RE larger than the free green electricity market. Policy measures such as a renewable portfolio standard or a feed-in-renewable-energy-tariff are then implemented to reach the target.

Optimal penetration level for wind energy

Static economic analysis identifies the recommended penetration level for "mature" RETs as the market share at which the *economic cost per kWh of the marginal RET-generator* equals the *economic value of the savings in replaced thermal power generation*. At this penetration level, the *incremental cost* of the marginal RE-project equals the *avoided damage costs* of replaced thermal power. Damage costs comprise (i) the environmental costs of thermal power and (ii) a risk premium reflecting the negative macro-economic impacts of fluctuating prices in fossil fuels.[9]

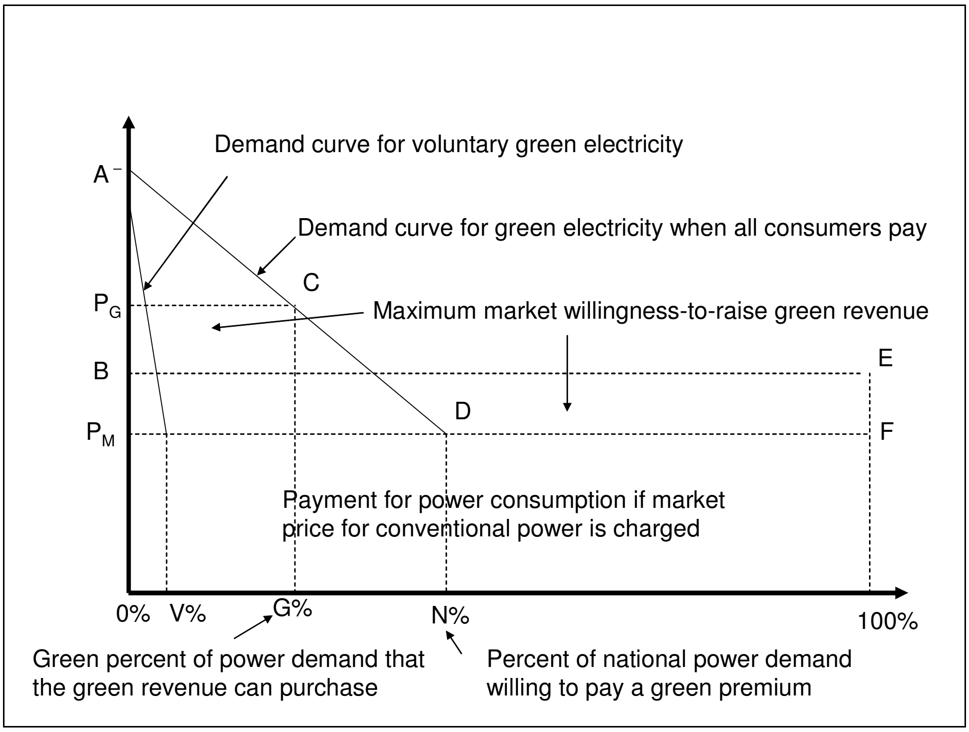
This is the concept behind the *supply-curve approach*, which identifies the optimal penetration level of renewable energy in the national generation mix at the point of intersection between the LRMC of supply curve for renewable energy with the LRMC of thermal power. It "correctly" identifies the economic optimum penetration if the "consumption value" of RE-power is internalized in the cost per kWh of RE-power and the LRMC for thermal power includes the cost of fuel price uncertainty. The "consumption value", being a side product of RE-power - like a CER/ERU in a CDM/JI project - is deducted from the cost of RE-production to yield the net cost of "raw power" injected into the national power system.

Quantification of the "consumption value" is, however, difficult:

1. One potential avenue is using data on consumer willingness to pay from green market surveys to establish a *demand-weighted average green electricity premium per kWh.*[10] One problem with this approach is that the question to pose in the survey, as argued in the section above, is how much consumers would be willing to pay if all consumers had to pay the same premium. The other problem is to find out what respondents mean with "green premium per kWh": is it *per kWh delivered green electricity* (what premium consumers think is reasonable to pay to generators using RET), or *per kWh consumed electricity, comprising conventional as well as X% green electricity*? If the premium per consumed kWh could buy 100% green electricity penetration there would be no problem, but it cannot; and consumers would hardly be willing to pay a demand weighted Y cents per kWh final consumption if the revenue succeeded in purchasing only a 1% penetration of green

[8] This is not totally correct. "Consequentialist consumers" may be willing to sign up for having a part of their electricity supply based on green power; a fact which is exploited in green electricity marketing by offering such a choice.
[9] An alternative approach is to incorporate the fuel risk directly in the cost of production per kWh by using a lower discount rate to deflate future fuel costs in annual O&M.
[10] Assume there are ten consumers, each having the same annual power demand. One is willing to pay a green premium of 10 cents one of 6 cents, one of 3 cents, the other 7 zero. The weighted green premium per kWh final consumption of electricity would be 1+0.6+0.3= 1.9 cents.

electricity! The question to pose, therefore, would be to ask for various penetration levels of green electricity how big an increase in the cost per kWh of final demand, the consumer would be willing to accept to pay. The *optimal penetration of green electricity* would then be the quantity of green electricity, for which there is a match between the amount of premium revenue consumers are willing to pay, and the premium revenue that is required to bring forward the supply.



The approach is explained in the chart above. $\mathbf{P_M}$ is the market price for thermal power, the price consumers pay (net of transmission and distribution) before the introduction of green electricity. **V** is the amount of green electricity that would be sold on a purely voluntary green market. **N** shows the amount of electricity – in percent of total – consumed by consumers who would be willing to pay something extra for green electricity, provided that all consumed kWhs would be charged the green electricity premium. The difference between 100% and N% shows the amount of national electricity consumed by consumers who would be unwilling voluntarily to pay any premium whatsoever for green electricity. The area $\boldsymbol{P_G CG0}$, showing the total green revenue that electricity consumers would voluntarily pay, is equal to the areas $\boldsymbol{BP_M FE}$ – the green electricity raised from consumers by charging all a bulk tariff of B – and $\boldsymbol{AP_G D}$ – the total payment to RET-generators for supplying the "optimal" green electricity quantity **G** at the required tariff $\boldsymbol{P_G}$.

2. An alternative approach *to establish it through a "political preference matrix*". The top political decision takers – represented by the Minister responsible for energy – can be presented with different sizes of green electricity premiums and associated additional RE-quantities. The chosen "quantity/cost-of-premium combination" reveals the "politically acceptable green premium", and hence the consumption value for that quantity.

The report “Economic and Financial Calculations Modeling for the Renewable Energy White Paper”[11], attempted a third and innovative approach, using the concept of a socalled “*socio-economic supply curve” for RET*. South African politicians are strongly interested in employment generation, macro-economic growth, black empowerment and poverty impacts. The supply curve report assumes that the political value of RE-investments in South Africa refers to its impact on employment (and GDP-growth). It therefore estimates the net employment generation per GWh per specific RET, and assigns a macro-economic value to this, which is deducted from the *economic cost of production* of the different RETs, to yield the national “socio-economic RE-supply curve”. The approach is quite innovative. Unfortunately, the authors forgot that the higher cost of renewable energy has to be financed by reducing demand in other parts of the national economy. They did not deduct the opportunity cost in terms of lost employment in the other parts of the economy from the employment generation created in renewable energy

[11] Conningarth Economists: “Economic and Financial Calculations and Modelling for the Renewable Energy Strategy Formulation with selection of the optimal mix (least cost) of technologies for fulfilling the 10 000 (4 000) GWh target a least cost for the South African society”. February 4, 2004.