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# RENEWABLE AND CONVENTIONAL ENERGY GENERATION

*COMPARING THE COSTS*

FRIENDS OF SCIENCE

# Contents

# RENEWABLE AND CONVENTIONAL ENERGY GENERATION

## COMPARING THE COSTS - EXECUTIVE SUMMARY

Proponents of wind and solar electricity generation plants contend that the costs of these plants are now, or soon will be, lower than those of conventional electricity generation plants based on nuclear energy, hydro or the combustion of fossil fuels. Is this true?

There are many different cost factors to take into account, including notably the initial capital costs of the plants and their operating, maintenance and repair costs; these ultimately are reflected in the purchasing utility's total expenditures over the life of the plants and the costs that are passed on to electricity consumers in the form of higher rates. Costs, however, are only one element to consider in determining the economic viability or merits of a plant; others include its capacity utilization (the average power generated as a percentage of the stated capacity, or "nameplate" capacity, of the plant); whether it is "dispatchable" (variable to meet changes in demand) or instead intermittent and unreliable; its ability to supply electricity at peak demand periods when it is most needed; and its effects on the market value ("pool price") of generation, especially when the electricity generated exceeds the demand

Since 2000, the actual costs of newly added wind and solar generation have significantly exceeded the costs of other sources of power generation. This is especially evident in Europe, where the capital costs of onshore wind projects per gigawatt (GW) of generation has been 16 times that of natural gas fired generation and that of solar PV on the grid has been 63 times that of natural gas fired generation. By 2014, the countries of the European Union had spent over 1.1 trillion euros (CDN $1.68 trillion) on wind and solar generation. Over the lives of the contracts existing in 2014, the EU countries made some 3.1 trillion euros (CDN $4.74 trillion) in financial commitments. In the province of Ontario, the government's granting of above-market feed-in-tariffs – "FIT" (a form of fixed, contracted subsidies) to renewables under 20-year fixed price contracts, with "first-to-the-grid" rights, has provided large subsidies valued by different sources from CDN $6.4 billion to $9.2 billion and left the provincial utility with up to $38 billion in long-term unfunded liabilities

The U.S. Energy Information Administration estimates the levelized capital and operating costs (LCOE) over the lives of new electricity generation plants that will enter service in the near future. The most recent estimates, for plants entering service in 2022, indicate that new natural gas combined cycle and gas advanced combined cycle will have the lowest cost (U.S. $57/MWh) among the dispatchable sources of generation. Among the non-dispatchable sources of generation, the lowest cost sources will be onshore wind ($64/MWh), hydroelectric ($66/MWh) and solar PV ($85/MWh).

Other sources challenge the EIA's LCOE methodology. Notably, the Institute for Energy Research observed that the EIA ignores the comparison between the cost of new generation and the cost of continuing to operate existing fossil fueled (mainly coal-fired) power plants to the end of their economic lives instead of shutting them down prematurely. It also questions the EIA's assumptions concerning the utilization rates of renewable energy plants and the prices of natural gas. It estimates the LCOE of existing conventional coal plants in 2015 to be U.S. $40/MWh and that of gas combined cycle plants to be U.S. $34/MWh.

The most fundamental challenges to the EIA findings are from experts who emphasize the differences in the costs and value of intermittent versus dispatchable electricity generating sources. They argue that the LCOE approach is flawed because it treats all megawatt hours supplied as a homogeneous product governed by the law of one price, and thus does not account for the fact that the value (wholesale market price) of electricity supplied varies widely over the course of a typical year. LCOE also ignores the necessary costs of backing up intermittent sources with conventional power (typically natural gas) and the many additional costs of the power grid operator needed to integrate wind and solar, along with the need for additional transmission lines.

Comparing the average household electricity prices in Europe and North America shows clearly that the price of power rises dramatically, as the proportion of photovoltaic and wind capacity per inhabitant rises. Prices in Germany and Denmark are almost three times higher than in the United States.

The higher costs quoted for renewable energy do not include most of the taxpayer subsidies provided to renewables.

If, as proponents of wind and solar claim, the economic costs of renewable energy generation will soon be less than those of conventional sources, they should have no objection if governments eliminate the present subsidies, above-market tariffs and portfolio mandates establishing minimum utility purchase requirements. It is telling that none of these advocates is proposing this in any jurisdiction.

## Introduction

One of the most hotly debated topics among those with an interest in electricity policy and system planning concerns the comparative cost competitiveness of present and future generation technologies. The issues involved are of major importance, because trillions of dollars in new investment are at stake. The countries and sub-state jurisdictions that make the wrong decisions may impose heavy cost burdens on their populations for decades to come, undermining their competitiveness and future living standards.

The purpose of this article is to examine the current evidence about the costs of renewable energy sources and those of other, more conventional, generation sources like coal and natural gas-fired plants and nuclear plants. Although the issues are, in some respects, quite technical, this article will attempt to describe them in terms readily understandable to the layperson. There is a risk that this may lead to over-simplification, for which I apologize in advance.

## Defining the Terms

The term “renewable energy” can be used to describe a broad range of energy sources that, in theory at least, are not limited in their production by the constraints of geological availability. These can be interpreted to include energy produced by wind, the sun, water flow or tidal movements (e.g. hydroelectricity), geothermal or biomass conversion and combustion. Of these sources, hydro-electricity contributes the most to electricity production today, but in most regions of the world there are limited opportunities for additional large-scale hydro developments. For several reasons, most new investment in renewables over the period since 2000 has been in wind and solar energy, the so-called “new renewables”, and so this paper will focus almost entirely on the costs of these sources.

## Costs

There are many ways to define and portray the costs of electricity generation sources:

- Capital costs are the costs of constructing the original system; they are usually paid up front before the project begins operating and are depreciated over time, often as determined by the accounting practices dictated by regulators;

- Operating and maintenance costs are the costs incurred during the production phase; these include notably the costs of fuel, salaries and other variable costs, as well as repairs;
- Subsidies are often “hidden costs” in the sense that these are often received by the producers or by the consumers of energy from governments and may or may not be reflected in the rates paid;
- Total expenditures offer a measure of the costs incurred by the contracting utility over the life of a contract.
- The costs to electricity consumers are subsumed in the electricity rates.

Costs, of course, are only one element in determining the economic viability or merits of a plant. The economically optimal electricity supply system may be affected by several other factors, including these:

- **The nature of electricity demand.** Electricity is needed to provide a wide range of energy services used in a modern economy, and the volume demanded varies considerably from hour to hour, day to day and season to season. Electricity generation sources that are constantly available and can be varied to match the changes in demand are far more valuable than generation sources that cannot do that.
- **The difficulty and expense of storing electricity.** Today there are only a few, quite expensive systems available for storing electricity during periods of production so that it can be used later when generators are not producing. The technologies for achieving large and low-cost storage are still some distance away. [1]
- **The fact that most conventional (fossil fuel, hydro and nuclear) generating technologies are “dispatchable”.** This means that they can be controlled by the system operator and can be turned off and on based primarily on their economic attractiveness at every point in time both to supply energy and to supply network reliability services (e.g. frequency regulation, spinning reserves). Conventional dispatchable generators are typically scheduled by the system operator to meet demand by dispatching the generators with the lowest marginal cost first and then moving up the “dispatch curve”, calling on generators with higher marginal costs until demand for energy is satisfied.
- **Differences in capacity utilization.** Some generation sources, like nuclear energy, are able to produce at very high rates of utilization, often exceeding 90%, whereas fossil fuel-based generators typically operate at about 85%, and renewable energy sources at much lower rates. Wind and solar energy capacity utilization varies sharply over time depending on when and how hard the wind blows and when and how directly the sun shines.
- **Whether total electricity generation exceeds demand.** In many places, renewable energy generators have been given contracts that assure them preferential access to the grid when they are able to produce; in those circumstances, the available generation may exceed the electricity demand in

[1] http://euanmearns.com/is-large-scale-energy-storage-dead/ “Total global storage capacity with pumped hydro added works out to about 500 only GWh, enough to fill global electricity demand for all of ten minutes.” April 2016

that jurisdiction, and the system operators may have to either curtail generation (i.e. pay generators not to produce) and/or export the surplus electricity to neighbouring utilities at distressed prices. The losses on sales and the costs of curtailment are then added on to ratepayers' bills.

- **Market distortions.** When wind and solar generators produce power at the same time as other generators in excess of demand, the oversupply also reduces the market value (i.e. the wholesale market price of electricity) and thereby reduces the value of all wind and solar power in the system.

## The Cost Experience to Date

In terms of capital and operating costs, total expenditures, and effect on consumer electricity rates, in the period since 2000 the costs of wind and solar power generation have significantly exceeded the costs of other sources of generation.

The countries of the European Union have made the largest expenditures on renewable energy generation. The main source of data on generation costs there is the European Observer, an organization that actively promotes increased use of renewable energy. According to data from this source, to the end of 2014 European Union countries spent about 1.1 trillion EUR (CDN $1.68 trillion) on large-scale renewable energy installations. This provided a nominal nameplate generating capacity of about 216 Gigawatts (GW), or nominally about 22% of the total European generation needs of about 1000 GW. The actual measured output by 2014 supplied by the renewables industry was 38 Gigawatts, or 3.8% of Europe electricity requirements, at a capacity factor of about 18% overall. Accounting for capacity factors, the capital cost of these renewable energy plants has been about 29 billion EUR (CDN $44.4 billion) per Gigawatt.

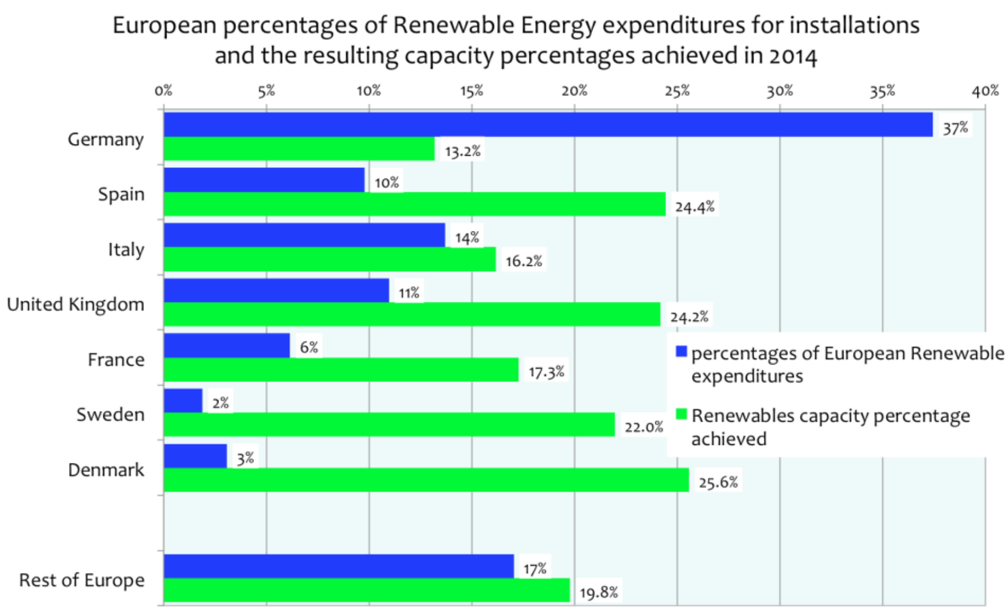
The following table from the European Observer indicates the capital costs per GW of wind and solar energy technologies actually built through 2014.

**EurObserv'ER data EU (28) 2014: comparison of capital costs**

| | Renewables Nameplate installed GW | Renewables Output achieved GW | Capacity percentage Energy Output / Nameplate installed | Renewables estimated capital expenditure US EIA data | Renewables approximate Cost / GW generation |
|---|---|---|---|---|---|
| Onshore Wind | 120.1GW 56% | 26.6GW 69% | **22.1%** | 436€ bn 39% | 16€ bn/GW |
| Offshore Wind | 9.2GW 4% | 2.2GW 6% | **23.4%** | 98€ bn 9% | 45€ bn/GW |
| Solar PV on grid | 86.5GW 40% | 9.5GW 25% | **11.0%** | 597€ bn 53% | 63€ bn/GW |
| Total | **215.9GW** | **38.2GW** | **17.7%** | **1,131€ bn** | **30€ bn/GW** |

***NOTE: for comparison Gas Fired Electicity Generation costs about 1€bn / Gigawatt***

Thus, the capital costs per unit of generation have ranged from 16 billion EUR (CDN $24.4 billion) per gigawatt for onshore wind to 63 billion EUR (CDN $96.1 billion) per gigawatt for solar PV on the grid, or an average of 30 billion EUR (CDN $45.8 billion) per gigawatt for the three main sources of renewable energy. The capacity factors actually achieved are important in determining these costs. In fact, the actual capacity figures vary considerably among the countries of Europe,[2] as shown in the following table.




[2] Denmark has a grid structure unique in the world. It is split with one half connected to Norway (which has ample hydro) the other connected to Sweden (substantial nuclear). "Spilling" an overabundance of wind to either does not reduce CO2. Denmark is still highly reliant on coal. Denmark is also very tiny; no location in Denmark is farther than 52 km (32mi) from the sea. Thus, the sea offers vast wind resources with little transmission line requirements inside the country.

The capital costs per onshore wind GW of generation were 16 times higher than for gas-fired generation and those for solar PV on the grid were 63 times higher than for gas-fired generation. The whole 1000 GW fleet of European electricity generation installations could have been replaced with lower capital cost gas-fired installation for the 1 trillion EUR of capital spent on renewables to 2014.

Over the lives of the renewable energy contracts, the combined capital and operating costs will be much higher. By 2014 the countries of the European Union had made a current and future financial commitment of some 3.1 trillion EUR (CDN $4.74 trillion) to renewable energy technologies. That commitment has continued to increase with further renewable installations into the future. 3.1 trillion euros is about the annual GDP of Germany and about 50% more than the annual GDP of either France or the United Kingdom.

There are many other examples of the high costs that have been incurred by jurisdictions that have emphasized the addition of solar and wind generation. For example, the province of Ontario has by far the most solar and wind generation facilities of any province in Canada. Currently, Ontario has 4200 MW of grid-connected wind generating capacity and 600 MW distributor connected wind capacity. For solar energy, there is 300 MW of grid-connected capacity and 2100 MW of distributor connected capacity.

At one time, the provincial government, which owns the Independent Electricity System Operator (IESO), purchased renewable energy through a competitive bidding process. To accelerate the pace of renewables acquisition, the province went to a system in which all the renewable energy sources were eligible to receive a feed-in-tariff (FIT) at above-market rates under 20-year contracts in which the rates were guaranteed for the life of the contracts. The initial rates for onshore industrial wind turbines were CDN 13.5 cents per kilowatt hour (kWh), four times the rates at that time for conventional energy. The rate set for solar PV was CDN 80.1 cents per kWh, 30 times the cost of conventional energy. Over time, the FIT rates were reduced but in 2017 rates for solar PV (rooftop) ranged from CDN 31.1 cents per kWh for projects less than 6 kW in size to CDN 20.7 cents per kWh for projects between 100 kW and 500 kW in size. The 2017 FIT rate for onshore wind projects was CDN 12.5 cents per kWh.

There are different ways of calculating the costs of the Ontario policies. In her December 2015 report, the Ontario Auditor General found that, from the beginning of the FIT program to the end of 2015, ratepayers had paid over CDN $9.2 billion more for renewable energy generation than if the government had continued with its previous competitive procurement policy. She also found that, from 2009 to 2014, ratepayers paid generators CDN $339 million to shut down their operations at times of electricity surplus in the province. During that same period, Ontario’s electricity exports to neighbouring jurisdictions cost ratepayers CDN $3.1 billion, as power was worth less than paid under the generous FIT contracts.

Scott Luft, a noted expert in utility economics and close follower of Ontario electricity trends, often reports on his blog "Cold Air" on the data publicly available and those he is able to obtain through Access to Information requests. In a July 23, 2017 article, he analyzed the growing subsidy to solar and wind energy in Ontario. He quantified the subsidy as the cost paid above the cost paid for other supply. Calculating the average cost of electricity is complex, so those interested in his methodology should read his analysis here.

http://coldair.luftonline.net/2016/07/the-growing-subsidy-of-wind-and-solar.html

He concludes that the average cost paid to all generators other than wind and solar generators in 2015 was CDN $71 per MW. (For comparison, the long-term contract price for power supplied by the Bruce Power nuclear station in Ontario is about CDN $68/MW.) Using data on the grid-connected generation capacity and the generation capacity "embedded" in distribution systems (mainly solar), the supply cost and the amount paid by ratepayers, he calculated that, since 2006, Ontario has spent over CDN $10 billion on solar and wind output. Calculating as a subsidy the amount paid to solar and wind generators due to contracting their generation above the average cost of all other generators, the total subsidy is CDN $6.4 billion. Annual subsidies to solar generators exceeded CDN $1.2 billion in 2015 alone, while those to industrial wind generators were about CDN $600 million. In 2015, solar and wind provided 8.3% of the electricity generated in the province but constituted more than 20% of Ontario's electricity supply costs.

As is the case in Europe, the future cost of renewable energy contracted by Ontario far exceeds the cost incurred to date. What worsens this situation is the fact that, as documented in two reports of the provincial Auditor General (in 2011 and 2015), this supply was entirely surplus to the province's requirements, and its value may be realized on resale of power from the Ontario system. Scott Luft analyzed the eventual cost of Ontario's contracted solar and wind energy supply in an article on February 14, 2017. According to his analysis, the currently completed solar contracts entail a current liability of CDN $37.9 billion (for production of about 4.3 terawatt hours of electricity a year). To calculate the asset value of this supply (the resale value of this power produced over 20 years), he used CDN $156.7 per MWh, the value of the projects most recently contracted under the Ontario 2016 electricity procurement. The CDN $156.7/MWh values the approximately 4.3 TWh of estimated annual output over the 20-year contract term at CDN $13.5 billion. With a contract cost being CDN $37.9 billion, the net liability of solar contracts is therefore estimated to be CDN $24.4 billion.

Ontario also has contracts for over 6,000 MW of wind capacity. Should all projects proceed to completion, Luft projects annual generation of about 16.8 TWh at a cost of CDN $2.1 billion per year – totaling CDN $42 billion over the 20-year contract terms. Again, valuing the production at the last contracted price ($85.9 MWh in the case of wind), the annual losses on resale would be CDN $684.2 million per year, and the 20-year term contract losses CDN $13.6 billion.

The CDN $13.6 billion net liability of wind added to the CDN $24.4 net liability of solar contracts produces a potential CDN $38 billion net liability.

Luft's analysis can be read here:

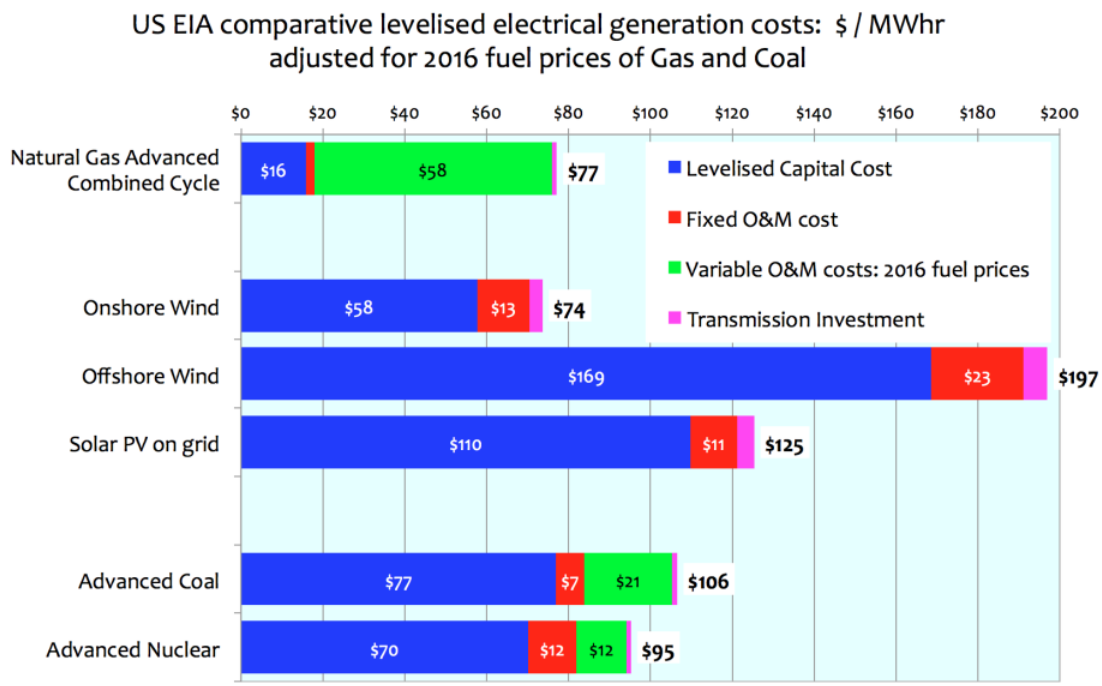
http://coldair.luftonline.net/2017/02/the-failure-of-global-adjustment.html

Germany is much farther down the track that Ontario is on, and its experience should be heeded. In July 2014, FinAdvice, a German M&A consulting company in the utility sector, published a report entitled, *Development and Integration of Renewable Energy: Lessons from Germany*. It described the financial impacts of Germany's feed-in-tariff program:

*"Germany's FIT program has cost more than $412 billion to date (including granted and guaranteed, but not yet paid, FIT). Former German Minister of the Environment Peter Altmaier recently estimated that the program costs could reach $884 billion (680 billion euros) by 2022. He added that this figure could increase further if the market price of electricity falls, or if the rules and subsidy levels are changed. It is estimated that Germany will pay $31.1 billion in subsidies in 2014 alone."*

## Projecting the Costs of New Generation

In the United States, the Energy Information Administration (EIA) reports on the comparative costs of different generation sources on a "levelized" basis. The levelized cost is essentially the expected real total cost (capital plus operating costs), in terms of dollars per megawatt/hour of different new generation technologies over the lives of the plants. The EIA updates these figures every few years. The following bar chart shows the EIA analysis prepared in 2014 projecting the costs of new generation sources in 2016.




Note that the levelized cost of onshore wind plants was estimated to be U.S. $74/MWh, even lower than the $77/MWh for natural gas advanced combined cycle, while the cost of advanced nuclear and advanced coal was considerably lower than the levelized cost of offshore wind or solar photovoltaic (PV) on the grid.

In the EIA's 2017 updated version of the levelized cost of new generation sources, it estimates the national average costs for generation entering service in 2022. The EIA report can be read here:

https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

Table 1 shows the 2017 estimates.

**Table 1**

**U.S. Average LCOE (2016$/MWh) for Plants Entering Service in 2022**

| Plant Type | Capital Cost | O+M | Transmission | Total |
|---|---|---|---|---|
| Dispatchable | | | | |
| Gas Combined Cycle | 13.9 | 42.2 | 1.2 | 57.3 |
| Gas Advanced CC | 15.8 | 39.4 | 1.2 | 56.5 |
| Advanced Nuclear | 73.6 | 24.3 | 1.1 | 99.1 |
| Non-dispatchable | | | | |
| Wind – Onshore | 47.2 | 13.7 | 2.8 | 63.7 |
| Wind – Offshore | 133.0 | 19.6 | 4.8 | 157.4 |
| Solar PV | 70.2 | 10.5 | 4.4 | 85.0 |
| Solar Thermal | 191.9 | 44.0 | 6.1 | 242.0 |
| Hydroelectric | 56.2 | 8.2 | 1.8 | 66.2 |

Note that, partly because of lower natural gas price assumptions, the natural gas-fired plants are now projected to have the lowest LCOE, followed by onshore wind. The surprising change from the 2016 figures is the projected reduction in the LCOE of solar PV to U.S. $85 per MWh.

These figures are the bases for the claims by renewables advocates that wind and solar energy are now at or approaching "grid parity" with conventional generation sources. Note, too, that the EIA did not even estimate the LCOE for new conventional coal plants, continuing (one assumes) with the policy assumptions established under the Obama Administration that no additional coal plants would be built.

## Challenges to the LCOE Methodology

Several experts have offered alternatives to the LCOE methodology for measuring the comparative costs of different electricity generation options. In July, 2016, the Institute for Energy Research (IER) observed that a deficiency of the LCOE analysis was the "*absence of any information about the cost of electricity from existing generation resources, even though those resources supply all of our electricity today and most of them could continue to supply reliable electricity at the lowest level for years – even decades – to come*".

Using data from the United States, the IER offered two new sets of data – one comparing the LCOE of existing generation at 2015 capacity factors and that of new generation at actual 2015 capacity factors (in contrast to the EIA-assumed capacity factors) and a bar chart showing their adjustments to EIA's methodology for reporting the LCOE of new resources using actual 2015 capacity factors and updated natural gas fuel price assumptions. See the following two illustrations.

**Table 2**

**U.S. Average LCOE (2013 U.S.$/MWh) for Plants in or entering Service in 2015**

| Plant Type | Existing Generation | New Generation |
|---|---|---|
| Dispatchable | | |
| Conventional coal | 39.9 | N/A |
| Gas Combined Cycle | 34.4 | 55.3 |
| Nuclear | 29.1 | 90.1 |
| Hydro | 35.4 | 122.2 |
| Dispatchable Peaking | | |
| Gas Conventional (CT gas) | 88.2 | 263.0 |
| Intermittent | | |
| Onshore wind* | N/A | 107.4 |
| PV solar* | N/A | 140.3 |

**Includes costs imposed on combined cycle gas.*

**Table 3**

**U.S. Average LCOE (2015 U.S. $/MWh) for Plants in or Entering Service in 2015**

| Plant Type | Existing Generation | New Generation |
|---|---|---|
| Conventional coal | 39.9 | N/A |
| Gas Combined Cycle | 34.4 | 55.3 |
| Nuclear | 29.1 | 90.1 |
| Hydro | 35.4 | 122.2 |
| CT Gas | 88.2 | 263.0 |
| Wind* | | 107.4 |
| PV Solar* | | 140.3 |

**Includes the costs imposed on combined cycle gas*

Three factors explain why these estimates provide an entirely different picture of the comparative costs of different generation sources than those prepared by the EIA. First, they illustrate the significantly lower cost of continuing to use existing generation sources that have already been largely depreciated in terms of their capital costs. Second, they show the effects of taking into account some of the systemic effects of integrating intermittent generation sources into electricity grids (i.e. the requirement to maintain and occasionally use combined cycle gas plants as backup capacity for the times when wind and solar are not available but demand must be met). Third, they show the results of lower price assumptions with respect to natural gas.

The Institute for Energy Research report, released in July 2016, can be found here:

https://www.instituteforenergyresearch.org/wp-content/uploads/2016/07/IER_LCOE_2016-2.pdf

Using the Institute for Energy Research methodology, the best policy and electricity planning approach clearly would be to extend the life of existing generation plants. In this regard it is interesting to note that many older nuclear plants been up-rated from their original nameplate capacity. In the United States, the Nuclear Regulatory

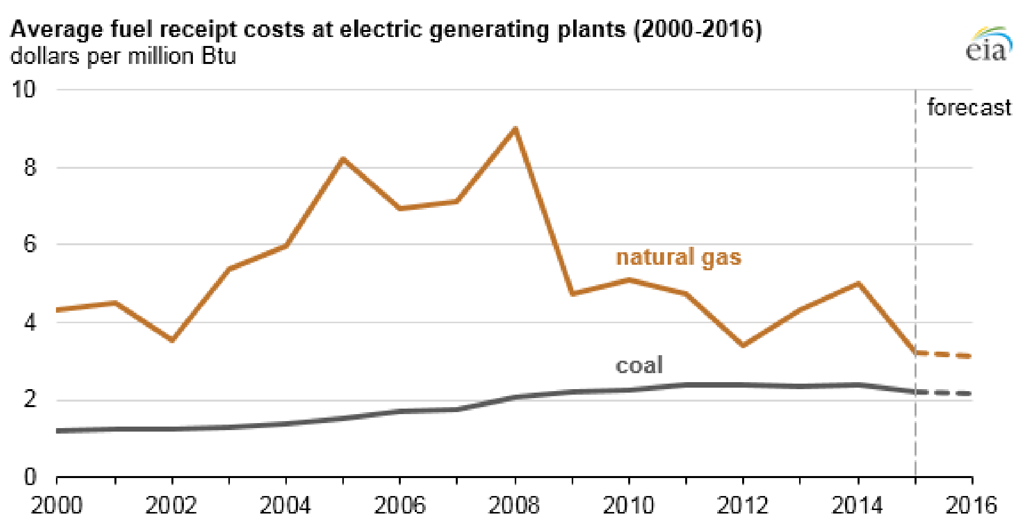
Commission has licensed most nuclear plants for 60 years, and potentially 80 years, of operation.

The cost of closing conventional fuel plants before the end of their economic lives can be high. The province of Alberta, Canada, recently decided that, as part of its climate change strategy, it would phase out all coal-fired plants (with a present capacity of about 6300 MW) by 2030, replacing two-thirds of that capacity (i.e. 4200 MW) by renewable energy and one third by natural gas-fired plants. The cost of this, in terms of compensation to the existing plant operators, will be CDN $97 million per year over 14 years, beginning in 2017, for a total cost of CDN $1.36 billion. This, of course, does not include the higher costs to consumers of more expensive electricity nor the economic losses to formerly coal-producing communities.

## Stability of Future Fuel Costs

One advantage of solar and wind plants frequently cited is the comparatively low operating costs, due largely to the fact that the “fuel costs” of solar and wind are effectively zero. This ignores the other operating costs related to operations and maintenance, as well as the significant costs of providing backup natural gas generation and balancing and integration costs.

Estimates of the LCOE of fossil fuel powered plants are much affected by the extent to which the markets for these fuels are volatile or stable. In recent years in both North America and Europe, natural gas prices have demonstrated wild swings as supply and demand changes. Coal-fired plants, by comparison, have fuel costs that are lower and more stable over time. The following graph from the U.S. Energy Information Administration illustrates this.



## The Systemic, or Grid-Wide, Costs of Intermittent Energy

A number of analysts have examined further the differences between the costs of intermittent and dispatchable electricity generating technologies. A seminal paper was written by Paul Joskow of the Alfred P. Sloan Foundation and MIT in 2011. The paper can be found here.

https://economics.mit.edu/files/6317

In his abstract, Professor Joskow wrote, "*the standard life-cycle cost metric utilized is the 'levelized cost' per MWh supplied. This paper demonstrates that this metric is inappropriate for comparing intermittent generating technologies like wind and solar with dispatchable generating technologies like nuclear, gas combined cycle, and coal. Levelized cost comparisons are a misleading metric for comparing intermittent and dispatchable generating technologies because they fail to take into account differences in the production profiles of intermittent and dispatchable generating technologies and the associated large variations in the market value of the electricity they supply. Levelized cost comparisons overvalue intermittent technologies compared to dispatchable base load generating technologies. Integrating differences in production profiles, the associated variations in the market value of the electricity at the times it is supplied, and the expected life cycle costs associated with different generating technologies is necessary to provide meaningful economic comparisons between them.*"

To be more specific, the Joskow paper makes these points:

- The LCOE approach is flawed because it treats all megawatt hours supplied as a homogeneous product governed by the law of one price, and thus does not account for the fact that the value (wholesale market price) of electricity supplied varies widely over the course of a typical year.
- Different intermittent generating technologies (e.g. wind versus solar) also can have very different hourly production and market value profiles, and indeed, specific intermittent generating units using the same technology (e.g. wind) may have very different production profiles depending on where they are located.
- Electricity that can be supplied by a wind generator at a levelized cost of 6 cents per kilowatt hour (KWh) is not "cheap" if the output is available primarily at night when the market value of electricity is only 2.5 cents per KWh. Similarly, a combustion turbine with a low expected capacity factor and a levelized cost of 25 cents per KWh is not necessarily "expensive" if it can be called upon reliably to supply electricity during all hours when the market price is higher than 25 cents per KWh.

- In effect, the electricity supplied by conventional plants and by renewable energy plants is not the same product.

LCOE analysis ignores the costs of backing up intermittent renewables and of the networks required to integrate them. Usually in North America, a large number of natural gas plants are required to stand ready, operating at very low capacity factors, to be available when demand is high and renewables generation is not available. Silvia Pariente-David, writing in the IAEE Forum in 2016, summarized the grid integration costs.

*"The system operator, and the ratepayers, pay twice for generation capacity. Integrating wind and solar variable energy into power systems causes costs elsewhere in the system. Examples include distribution and transmission networks, short-term balancing services, provision of firm reserve capacity, a different temporal structure of net electricity demand and more cycling and ramping of conventional plants. Typically, these "integration costs" are of three types: grid costs, balancing costs and the "adequacy costs", or "utilization effect on conventional power plants".*

She went on to describe a less well known but important consideration, the "merit order" effect of renewable energy (RE).

*"RE penetration affects the revenues and margins of conventional power plants by lowering wholesale electricity prices and peak prices and by reducing the volume of electricity produced by thermal plants. Wholesale prices fluctuate between zero when renewables are at the margin (or even negative when low demand coincides with a very high level of wind for instance) and the variable cost of fossil fuel-fired plants when the latter are at the margin.*

*In a merit order based on marginal cost, RE plants will be dispatched first, as they have a zero-marginal cost. As the RE capacity increases, conventional fossil fuel power plants move to the right of the merit order curve and their utilization is substantially reduced. In Spain, effective operations of CCGT fell from over 4000 hours in 2008 to 1000 hours in 2014. Not only do they not cover their fixed investment costs, but they also risk being decommissioned if they run too few hours to cover their fixed O&M. However, these plants are needed to provide the system flexibility to integrate a high level of RE. An issue for electricity systems is how to provide adequate compensation for this flexibility. Capacity mechanisms have been introduced in some European countries to remunerate that flexibility and avoid conventional power plant closure. However, capacity payments tend to create an oversupply of power generating capacity, further depressing prices. This affects negatively both the value of RE and conventional plants."*

The article can be found here:

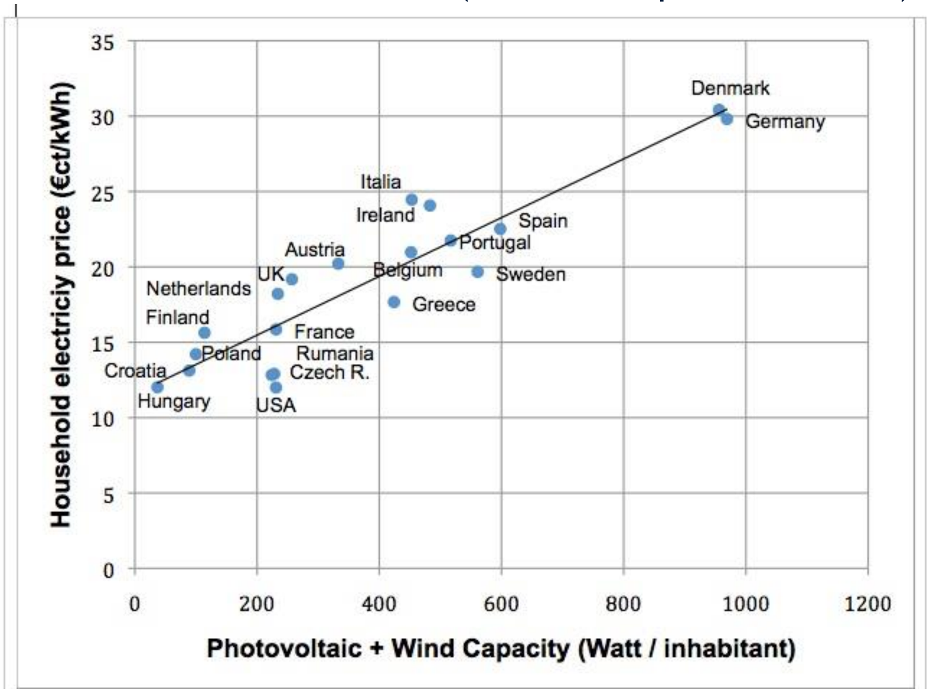
http://www.iaee.org/en/publications/fullnewsletter.aspx?id=39

In other words, governments, having created surplus generating capacity by mandates and subsidies to renewable energy plants, are now sometimes having to provide more subsidies to maintain the economic viability of the conventional plants renewable energy was intended to supplant, and then those subsidies have further unintended effects.

## Effects on Consumer Electricity Rates

The large investments in renewable energy capacity have an immediate consequence on the household electricity price in Germany, which is now, together with Denmark, the highest in Europe, due to all kinds of taxes added to the electricity price to pay for all the investments and additional costs. In 2017, the added cost (the so-called "EEG Umlage" or "EEG levy") was 6.88€ct/kWh, a factor of more than three higher than in 2010. The effect of increasing costs on household prices is illustrated in the following figure, showing that the German household electricity price is about three times more expensive than in the USA. A similar trend is visible for the electricity price for industry, although it is kept on purpose lower than the household price (the difference being paid by the households), to keep German industry competitive. The German government has announced plans to reduce the subsidized costs to the industry. This, in turn, will threaten the competitive viability of electricity intensive industries in Germany.

**Household Electricity Price versus the Installed Renewable Energy Capacity per Inhabitant for various Countries (in Euro cents per kWh for 2014)**



This figure illustrates well the relationship between higher levels of renewable energy generation capacity and increased costs to consumers.

## Subsidies

Despite a significant amount of information available about the subsidies provided to renewable energy sources, there seems to be little consensus about the actual effect of these on the prices received by renewables producers or the rates paid by electricity consumers. This subject is made more complex than it should be by the different meanings that have been given to the term “subsidy” and by the different methodologies that have been used to estimate the value of a subsidy. In general, subsidies are usually paid by governments (i.e. indirectly by taxpayers) or electricity ratepayers to certain groups and thus represent a transfer of funds from one group of citizens to others. When subsidies are provided to commercial firms, they distort the competitive marketplace.

In the case of solar and wind energy projects, the subsidies, or market advantages, provided by governments in Canada and elsewhere fall into several different categories:

- Funding of technology-specific research and development, conducted either in government research facilities or in private research laboratories
- Funding for technology demonstration projects
- Grants, contributions and low-interest loans made either to suppliers or purchasers
- Preferential procurement practices
- Tax incentives such as credits, deductions, and exemptions that are not provided to other firms and allowing firms to pass these benefits on to outside investors in the form of flow-through shares
- Preferences granted through regulation, including mandated minimum purchases by utilities
- Preferential, above-market utility rates, as used in “feed-in-tariffs” regimes, often guaranteed at fixed rates for the life of the contract
- Restrictions on local government ability to impose property and other taxes on solar and wind project sites

These and other incentives may be applied at federal and provincial government levels, creating multiple and often-duplicative subsidy possibilities. The pervasiveness and size of these subsidies makes it more difficult to judge the true competitiveness of renewable energy sources.

Whether they are good or bad may well depend on whether the benefit of government involvement outweighs the costs of the distortion.

I described the extensive subsidies provided to solar and wind energy in Canada in a recent article posted on the Friends of Science website. It can be read here:

http://blog.friendsofscience.org/wp-content/uploads/2017/11/SUBSIDIES-TO-SOLAR-AND-WIND-ENERGY-IN-CANADA---AN-INVENTORY-draft-2.pdf

## Conclusion

Electricity consumers in Europe and North America have paid significantly higher prices as a result of the decisions by governments and the utilities they control to invest in wind and solar energy generation rather than lower cost conventional generation. These decisions have added many billions of dollars in costs for residential and commercial consumers as well as electricity-intensive industries in those regions. The effects of these distortions will probably be felt for decades.

There are varied methodologies for calculating the future costs of generation technologies, each of which offers different insights. A central question is whether the LCOE approach adequately addresses the system-wide costs that arise from the intermittent nature of renewable energy production; based on present evidence, it appears that it does not.

The debate about whether the costs of renewable generation options will soon drop to the point at which they are competitive with conventional generation seems likely to continue. If this were to become true, it would be a good development, in that it would add to the diversity of the electricity supply system. In such a case, however, one assumes that governments could soon remove the present subsidies, mandates and special FIT-like incentive rates; it is telling that this is nowhere being proposed.

*About the author:*

*Robert Lyman is an Ottawa energy policy consultant who was a public servant for 27 years, prior to that a diplomat for 10 years.*

About

Friends of Science Society is an independent group of earth, atmospheric and solar scientists, engineers, and citizens, celebrating its 16th year of offering climate science insights. After a thorough review of a broad spectrum of literature on climate change, Friends of Science Society has concluded that the sun is the main driver of climate change, not carbon dioxide ($CO_2$).

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