Economic Analysis

Andrew Kusiak
Intelligent Systems Laboratory
2139 Seamans Center
The University of Iowa
Iowa City, Iowa 52242 - 1527
andrew-kusiak@uiowa.edu
Tel: 319-335-5934 Fax: 319-335-5669
http://www.icaen.uiowa.edu/~ankusiak

Mapping Energy Value Stream

- ✓ Value stream encompasses all activities creating values
- ✓ Scope of value stream: Entire process
- ✓ End activity: A Customer
- ✓ Objects in the value stream: materials, components, people, money, information, etc.

Mapping Energy Value Stream

Types of value stream maps based on the flow:
- ✓ Material
- ✓ Information

Types of value stream maps based on the time and objectives:
- ✓ Current conditions
- ✓ Ideal state
- ✓ Future state (e.g., 3-6 months from now)

Mapping Energy Value Stream

Purpose of value map:
- ✓ Communicate
- ✓ Discover waste
- ✓ Identifying sources of waste
- ✓ Plan actions to eliminate the waste

Mapping Energy Value Stream

Analyzing value based on the value map:
- ✓ Who is the end-customer?
- ✓ What value do customers buy?
- ✓ What stream of activities leads to this value?

Mapping Energy Value Stream

- ✓ Value stream maps of importance
- ✓ Commonality with the process modeling methodologies

Turbine Installation Cost

- ✓ Installation costs include a foundation, normally made of reinforced concrete, road construction (necessary to move the turbine and the sections of the tower to the building site), a transformer (necessary to convert the low voltage (e.g., 475 V) current from the turbine to, e.g., 10-30 kV current for the local electrical grid, telephone connection for remote control and surveillance of the turbine, and cabling costs, i.e., the cable from the turbine to the local 10-30 kV power line

Installation Costs Differ

- ✓ The cost of roads and foundations depends on soil conditions, i.e., building a road capable of carrying all turbine components
- ✓ Distance to the nearest highway
- ✓ The cost of getting a mobile crane to the site
- ✓ The distance to a power line suited to handle the turbine power
- ✓ Transportation costs of all turbine components can not be ignored
- ✓ An Internet connection and remote control center is necessary, however, the cost is usually low

Economies of Scale

- ✓ Connecting many turbines in the same location offers cost advantages
- ✓ Yet, the electric grid limits to the amount of power it can handle
- ✓ The grid may need to be reinforced, e.g., the high voltage electrical grid need to be extended
- ✓ Numerous parties may be involved in the grid modification, which is usually location (e.g., state) dependent

Operation and Maintenance Costs for Wind Turbines

- ✓ Wind turbines are designed to operate for 120,000 + hours over the design lifetime of 20 + years
- ✓ Data shows that maintenance cost is typically low for new turbines and it increases as the turbines age (which is natural)
- ✓ The terms of maintenance contacts vary, form fixed annual cost to the cost per service performed (expect growing competition in this area)

Economies of Scale

- ✓ Besides the economy of size of an individual turbine, the wind park economy of scale is of importance
- ✓ The economy of scale benefits stem from maintenance, administration, and so on
- ✓ This is particularly true for rotor blades and gearboxes that may be overhauled in batches rather than individually
- ✓ The price of a new set of rotor blades, a gearbox, or a generator may be in the order of magnitude of 15-20 % of the price of the turbine

Turbine Design Lifetime

- ✓ Wind turbines are usually designed to last, e.g., 20 - 25 years
- ✓ Designing components to last longer might be a waste
- ✓ The designed lifetime, e.g., 20 - 25 years, needs to be carefully evaluated as it impacts the individual system and component design/selection
- ✓ The actual lifetime of a wind turbine depends both on the quality of the turbine and the local climatic conditions, e.g., turbulence at the site
- ✓ Offshore turbines may last longer, due to lower turbulence at seas

Income from Wind Turbines

Energy Output from a Wind Turbine

- ✓ The energy production of a wind farm varies with the windiness of the site
- ✓ The sensitivity of energy production in the wind speed varies according to the probability distribution of the wind

The Availability Factor

- ✓ Wind turbines undergo scheduled and unscheduled maintenance
- ✓ Turbines achieve availability factors above 98%, i.e., the machines are ready to run more than 98% of the time
- ✓ The total energy output is generally affected less than 2%, as wind turbines seldom undergo scheduled maintenance during high winds
- ✓ Such a high degree of reliability is remarkable, compared to other technologies
- ✓ The availability factor is therefore usually ignored in economic analysis

Wind Energy and Electricity Rates

- ✓ Electric utilities are interested in purchasing energy during the peak loads as this way they avoid running less efficient generating units
- ✓ Electric utilities may use a variable rate depending on the time of day the electricity is purchased

Environmental Credit

- ✓ Governments promote the use of renewable energy sources
- ✓ Environmental credits are often offered to wind energy utilities and turbine manufacturers
- ✓ The PTC (Production Tax Credit) legislature is frequently acted on and extended by the US Congress

Capacity Credit

- ✓ Large consumers of electricity may be charged for the energy (kWh) they use, and for the maximum amount of power (kW) they draw from the grid
- ✓ The reason is that the electric utilities need to maintain higher total generating capacity
- ✓ A collection of wind turbines can be considered as "negative consumers" allowing utilities to postpone installing additional generating capacity
- ✓ Non-utility operated turbines may expect a capacity credit payment from large utilities

Reactive Power Charges

- ✓ Most wind turbines use asynchronous (induction) generators
- ✓ These generators require current from the electrical grid to create a magnetic field inside the generator which impacts the alternating current in the electrical grid (phase-shifting)
- ✓ This may decrease (and in some cases increase) the efficiency of electricity transmission in the nearby grid, due to reactive power consumption
- ✓ Wind turbines are usually equipped with switchable electric capacitor banks that partly compensate for this phenomenon
- ✓ Non-compliance with the reactive power requirement may involve charges

Basic Economics of Investment

Social Return from Investment in Wind Energy

- ✓ Wind turbines provide a society with is pollution-free electricity
- ✓ An investment in a wind turbine provides electricity, that in turn leads to financial (cash) return
- ✓ This is important as the electricity prices are likely to at least follow or more likely exceed the inflation level in years to come

Wind Energy Economics

There is no Such Thing as a Single Price for Wind Energy

- ✓ Wind speed determines the amount of electricity produced and this way the electricity price

Pitfalls of Wind Energy Cost Analysis

- ✓ Many studies of the cost of wind energy and other renewables are not accurate due to the lack of understanding of both the technology and the economics involved
- ✓ Frequently people who understand the economics do not understand the technology and vice versa - and sometimes neither!
- ✓ Even trained economists have produced misleading comparisons of costs of different energy technologies

Asset Depreciation

- ✓ Depreciation is simply defined as the decline in the capital value of an investment using the internal rate of return as the discounting factor
- ✓ Asset depreciation can be tricky to compute due to unknown future income from the investment
- ✓ Many are surprised by this and confuse accounting (tax) depreciation with economic depreciation
- ✓ Accounting (tax) depreciation uses a simple formula to find the actual cost of energy per kWh based on the known values

Prices and Costs are Two Different Concepts

- ✓ Non-economists use the terms cost and price as synonyms
- ✓ The price of a product is determined by supply and demand for the product
- ✓ Some assume that the price of a turbine is cost plus profit, which is not the case in wind energy
- ✓ Some manufacturers deliver complete turnkey projects including planning, turbine nacelles, rotor blades, towers, foundations, transformers, switchgear and other installation costs including road building and power lines
- ✓ Other deliveries are nacelles only, or all variations in between

Prices and Costs

- ✓ Manufacturers' sales figures may include service and sales of spare parts
- ✓ Manufacturers' sales include licensing income
- ✓ Prices may vary significantly between markets, e.g., high wind turbines and low wind turbines
- ✓ The patterns of sales, types of turbines, and types of contracts vary significantly and unsystematically from year to year
- ✓ Prices should be obtained from price lists

Installation Cost

- ✓ Installation costs may include extension of the electrical grid and grid reinforcement
- ✓ The cost of cabling can be significant, and therefore it matters if a wind farm is located next to an existing, e.g., medium voltage power line (9 - 30 kV)

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Wind Energy is a Resource Extracting Technology

- ✓What is the average cost of crude oil?
- ✓ In Kuwait the cost may be $1 per barrel, in the North Sea, it may be $15 per barrel
- ✓ What is the average cost of wind energy?
- ✓ The answer may be similar

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Mistakes with Capacity Factors

- ✓ The capacity factor is the annual energy production divided by the theoretical maximum energy production if the turbine was running at its rated power all the year
- ✓ The capacity factor for a wind turbine is around 25-30%,
- ✓ It is definitely not desirable to increase the capacity factor for a wind turbine, as it would be for technologies where the fuel is not free as it impacts the cost per kWh
- ✓ In the final analysis, what counts is the cost per kWh of the energy produced, not the capacity factor

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Land Lease

- ✓ Treating compensation to land owners where the turbines are placed as a cost of wind energy is misleading
- ✓ Actually, it is only a minor share of the compensation which is a cost, namely the loss of crop on the area that can no longer be farmed, plus a possible nuisance compensation in case the farmer has to make extra turns when plowing the fields underneath the wind turbines
- ✓ It is not a cost to society, but it is a transfer of income (profits) from the wind turbine owner to the land owner
- ✓ Such a profit transfer is called by economists a land lease
- ✓ A lease payment does not transfer actual resources from one use to another
- ✓ Example fee: $4,000/year/turbine

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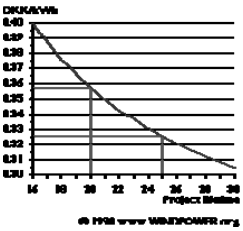

Economics of Offshore Wind Energy

- ✓ An important factor for offshore wind energy becoming more economic is that the cost of foundations has decreased dramatically
- ✓ See based wind turbines should have a longer lifetime due to lower turbulence (25 – 50 years vs ~20 – 25 years)

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