Northwest Power and Conservation Council

April 30, 2013

MEMORANDUM

TO: Council Members

FROM: Charlie Black and Steven Simmons

SUBJECT: Primer on Levelized Cost of Energy

Staff has prepared another in a series of primers designed to build up a framework for understanding power planning issues. Last month, we covered the topic of generating resources, including details on natural-gas fired power plants. This month's primer continues with the resources topic but with an emphasis on financial tools used for resource costing and evaluation.

The concept of levelized costs of energy will be covered at a high level. The concept will then be applied to two examples. Picking up with last month's theme, a natural gas-fired combined-cycle combustion turbine will be analyzed in terms of its levelized cost of energy, along with a utility-scale solar photovoltaic plant.

Attachment: Primer on Levelized Costs of Energy

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Primer

Comparing Electric Resources: Levelized Cost of Energy

Power Committee Meeting
Charlie Black and Steve Simmons
May 7, 2013

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Topics

- What is the levelized cost of energy (LCOE)?
- In what ways do we use it?
- How do we calculate it?
- Examples
- What are its strengths?
- What are its limitations?

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What is the Levelized Cost of Energy?

- Indicates the cost of <u>energy</u> for a specific resource over its productive life
- Typically expressed in units of dollars per megawatt-hour (e.g., $18 per MWh)
- Dollar values are converted to a specific base year amount (e.g., constant 2012 dollars)

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What is the Levelized Cost of Energy?

- Metric that allows the average life-cycle costs of different types of resources to be compared
  - Some resources have higher proportion of fixed costs; other resources have higher proportion of variable costs
  - Some resources produce (or conserve) power on a continuous basis; others operate less often
  - Different types of resources have varying productive lives, different on-line dates, etc.
  - Cash flows can vary – some have more up-front costs, others have more costs spread out over time
- Levelized cost of energy is a metric for making simplified economic comparisons

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In What Ways Do We Use It?

- MicroFin model *calculates* levelized cost of energy for generating resources
- ProCost model *calculates* levelized cost of energy for energy efficiency resources
- Levelized fixed costs for candidate new generating resources and energy efficiency resources are *used* as inputs to AURORA and the Resource Portfolio Model

How Do We Calculate It?

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:
t = period
n = number of periods (years)
r = discount rate
I_t = investment cost in period t
M_t = operation and maintenance cost in period t
F_t = fuel cost in period t
E_t = energy production in period t

Key Inputs

- Project life
- Energy production or savings
- Capital costs
- Fuel costs
- Operation and maintenance costs
- Discount rate

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Net Present Value

To calculate the levelized cost of energy, the concept of net present value is applied

- Financial technique for converting future streams of cash flows into a single dollar amount, expressed in a constant base year's dollar value
- Results in more of an apples-to-apples comparison

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Examples

- Combined-cycle combustion turbine generating project
- Utility-scale solar photovoltaic generating project

Evaluating and Comparing Generating Resources

Combined-Cycle Combustion Turbine Project	Utility-Scale Solar Photovoltaic Project
Uses sophisticated gas and steam turbines	Uses solar panels and inverters
Can generate a lot of power – 250-390 MW capacity	Can be smaller – 10-20 MW increments
Dispatched based on relative prices for power and gas, and system needs (assume 85% capacity factor)	Generation not dispatchable – depends on solar radiation at project site (assume 26% capacity factor)
Requires natural gas supply and pipeline infrastructure to deliver it – subject to price uncertainty	Does not consume fuel – no infrastructure requirements or costs
Emits greenhouse gases	No emissions
Project life 30 years	Project life 25 years

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Combined-Cycle Combustion Turbine

Let's build a 390 MW CCCT with a 2020 in-service date. Construction would begin in 2017.

Overnight capital costs (in 2012 dollars) are estimated to be $429 million – which will need to be financed.

Then we need to estimate annual costs to generate and transmit electricity. We'll need assumptions on:

- The amount of power it will generate annually (capacity factor)
- Expected heat rate (turning fuel into electricity)
- Expected fuel prices over time
- Expected emissions and emission costs over time
- O&M to keep it running along with Transmission and Integration

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Combined-Cycle Combustion Turbine

Once the cost assumptions are complete, an annual CASH FLOW diagram can be developed which spans the expected lifetime of the plant.

Then the CASH FLOW for each year is discounted to the PRESENT VALUE

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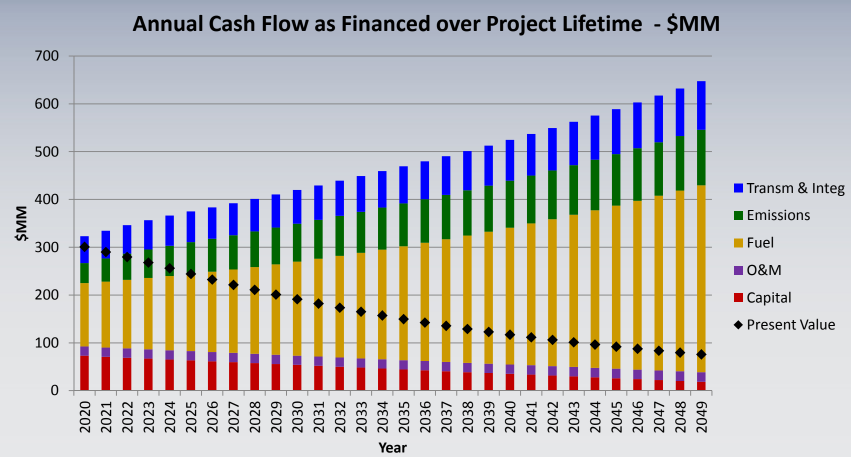
Combined-Cycle Combustion Turbine



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Combined-Cycle Combustion Turbine

The PRESENT VALUES are summed across the lifetime of the plant to produce the NET PRESENT VALUE (NPV)

Finally the NPV is annuitized into a single levelized payment and is normalized by the expected annual power production to form the LEVELIZED COST in $/MWh

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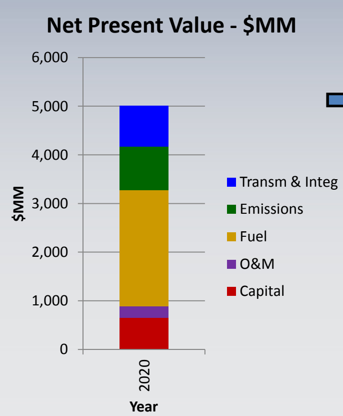
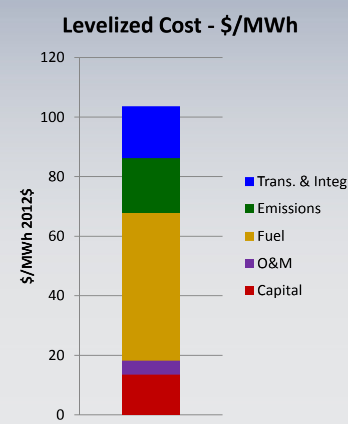
Combined-Cycle Combustion Turbine





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Utility-Scale Solar Photovoltaic

Next, build a 20 MW Solar PV unit with the same 2020 in-service date. Construction would begin in 2019, and it would be expected to operate until 2044

Overnight capital costs (in 2012 dollars) are estimated to be 65 $MM – which will need to be financed.

Then we need to estimate annual costs to generate and transmit electricity. So we need assumptions on:

- The amount of power it will generate annually (capacity factor)
- O&M to keep it running along with Transmission and Integration
- Adjustments for tax credits

With all of this – we can develop the CASH FLOW, NPV and LEVELIZED COST OF ENERGY for the plant; it looks different from the CCCT.

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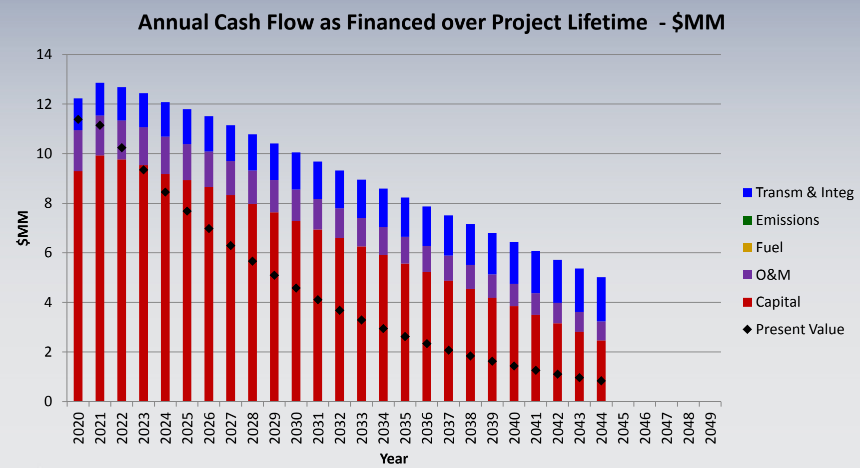
Utility-Scale Solar Photovoltaic



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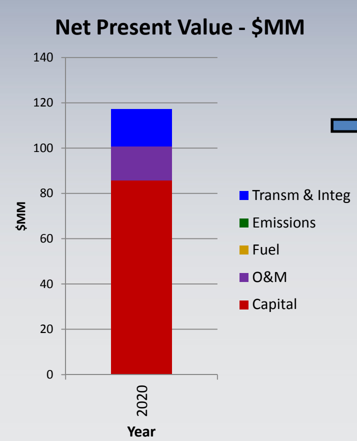
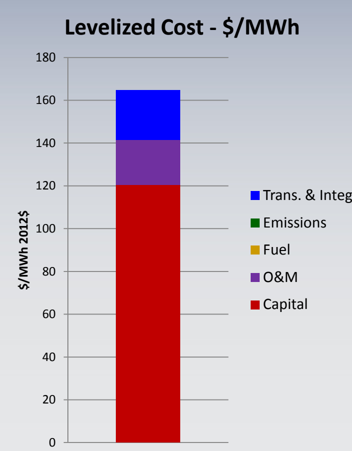
Utility-Scale Solar Photovoltaic





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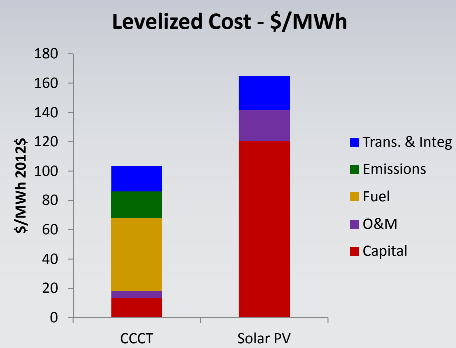
Levelized Costs of Energy

Now we are ready to compare our large CCCT plant with our small Utility Scale Solar PV plant – at least in terms of the cost of power produced, and the relative proportion of variable and fixed costs between the technologies



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Strengths

- Simple, straightforward
- Facilitates direct comparison of energy costs across a wide range of different resource types
- Can be useful for rough screening

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Weaknesses

- Only provides partial information
  - Just addresses energy, not capacity or flexibility
  - Does not reflect uncertainty (e.g., fuel price)
  - Does not capture differences in how resources operate (e.g., baseload vs. dispatchable vs. intermittent)
  - Does not show if a resource helps meet power system needs
- Integrated portfolio modeling is needed to provide a more meaningful comparison

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