Valuing Renewable Generation and Other Technology: A Finance-Accounting Oriented Survey

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### OVERVIEW: TRADITIONAL ELECTRICITY COST MODELS IN NO LONGER WORK

<table>
<thead>
<tr>
<th>Risk</th>
<th>Just as Investors Understand That…...</th>
<th>Energy Planners/Policy Makers Must Also Recognize That…...</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected returns (profits) cannot be separated from expected investment risks</td>
<td>A technology’s cost, unadjusted for its market risk, is meaningless</td>
</tr>
<tr>
<td>Portfolios</td>
<td>A diversified portfolio is the only effective risk-hedging strategy</td>
<td>“Least-cost” analysis is no substitute for energy portfolio diversification</td>
</tr>
<tr>
<td>Measurement</td>
<td>Accounting profits are not a good predictor of a firm’s future potential, strategic options and market share</td>
<td>“Least-cost” analysis does not capture all dimensions of a technology’s cost and value</td>
</tr>
</tbody>
</table>
Principal Analytic Results—Twelve Years of Research in Three Minutes:

- Standard, finance-oriented valuation models show that the kWh-cost for most renewables is less than gas-fired electricity
  - Reflects market risk and the effect of taxes
  - Excludes environmental externality, flexibility and other additional values

- Adding renewables to a fossil generating portfolio reduces overall generating cost as well as risk
  - This result derives from basic portfolio theory
  - Most renewables are zero-beta or “systematically riskless” assets

- Experience in other industries suggests that exploitation of broadly-applicable technologies requires changes in organizations, supporting systems and infra-structure and can produce benefits not easily conceived in advance
  - Renewables/DG: changes in network organization, regulation & pricing
  - Modernization focus: “Informated” networks
    - Basis for re-conceptualized electricity production/delivery system
VALUATION IN THE PRESENCE OF
TECHNOLOGICAL CHANGE
EVALUATING NEW TECHNOLOGY
Technologies Provide a Bundle of Benefit-Cost Attributes

• Initial & Operating Cost
• Product Throughput
• Product Quality
• Risk, Flexibility/Reversibility
• Strategic Options & Capabilities
• Environmental Effects

Most Attributes Have No Direct Accounting Measure
TRADITIONAL COST MODELS NO LONGER WORK:

Difficulty Conceptualizing/Quantifying Benefits and Reflecting Market Risk

- Traditional Cost Models often fail to identify promising innovations
  - Legacy of American Manufacturing:
    - Steel mini-mills, CAD, CIM, robotics…

- They Were conceived in a different technological era
  - Do not work well for DG/renewables and other passive, capital-intensive technologies—e.g. fax machines

- They produce “rule-of-thumb” valuations that ignore taxes and risk differentials…
  - But, fossil prices vary *systematically*—non-diversifiable risk
  - Costs of passive/capital-intensive renewables are systematically riskless
    - Financial properties mimic US Treasury obligations
Today’s Cost & Value Measures Conceived in Context of 19th Century Organizations and Technology

- **Discounted Cash Flow (DCF) Formalized in the 1940's**
  - Values Technologies/Processes Using Attributed Direct Cash Flows Only
    - Ignores Overheads - Assumed Small, Not-Controllable
    - Cannot Express *Quality, Strategic/Capability* Attributes

- **Cash-Flow Based Valuation (e.g. DCF) Conceived in an Era of Active, Expense-Intensive Technology**
  - Machines 'Wear Out' With Use
    - Costs Readily 'Matched' to Outputs by Accountants
    - Low Capital/High Operating Costs
  - Low Rates of Technological Progress
    - Replace Machine When: Running Costs$_{old}$ > Total Costs$_{new}$
    - Accounting Reasonably Serves This Purpose
Yesterday's Project Evaluation Techniques No Longer Work

• Today's Technology Is Passive / Capital-Intensive / Infinitely-Durable
  — Low Expense/High Capital Costs
    – Asset Replacement Not Driven by 'Wear & Tear'
  — Costs Not Readily 'Metered' -- 'Matching' Cost & Output Difficult
  — “Cost Saving” Largely Affects Overheads
    – Traditional Accounting Does Not 'See' Resulting Cost Reductions

How Do You Value A Fax Machine Using the Standard Accounting Model?
True Cost Drivers: The Limits of Our Accounting Vocabulary

- Accounting Costs Differ from True Cost Drivers
  - $/mile and FedEx
  - Is volume (kWh’s) the only cost driver for electricity?

- $/Unit Masks the True Cost of Activities
  - Manufacturing— Activity-Based-Costing (ABC) demonstrated the cost of producing waste material and defective products
    - Identify waste and defectives as separate “outputs”
    - Showed that dirty processes which require subsequent cleanup are often more costly

$/kWh is an incomplete, Fordist Era measure that often ignores quality (including overhead reductions) and other attributes of renewables and other new technologies.
TRADITIONAL COST APPROACHES NO LONGER WORK:
THE LEGACY OF MANUFACTURING

- Traditional accounting-based benefit-cost techniques fail to identify promising innovations

- These techniques have a dismal record for picking winners:

<table>
<thead>
<tr>
<th>Year</th>
<th>Technology</th>
<th>Conclusion</th>
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</thead>
<tbody>
<tr>
<td>1960's</td>
<td>Computers</td>
<td>“Armies of Clerks are Cheaper”</td>
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<tr>
<td>1980's</td>
<td>Robotics</td>
<td>“Human Workers are Cheaper”</td>
</tr>
<tr>
<td>1980’s</td>
<td>CAD</td>
<td>“Engineers Are Cheaper”</td>
</tr>
</tbody>
</table>

In each case, cash-flow based valuations failed to consider **Risk, Complementarities, New Capabilities and Strategic Options**

*These same Techniques say Renewables are “Not Yet Cost-Effective”*
Traditionally, cost approaches no longer work. For example, in valuing Computer-Aided-Design (CAD):

- Analyses Based on Naive Benefit-Cost:
  - Engineering Salaries Saved Vs. CAD-Station Outlays
  - Did Not Value CAD's "Intangible" Benefits: Complementarities (Milgrom/Roberts, AER, 1990) and Capability Attributes

<table>
<thead>
<tr>
<th>Frequent product redesign</th>
<th>No obsolete product/inventory</th>
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<tr>
<td>Rapid response/throughput</td>
<td>More varied product line</td>
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<tr>
<td>Complementary benefits</td>
<td>Reduce set-up costs in computer-integrated manufacturing (CIM)</td>
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</tbody>
</table>

CAD helps firm retain customers—Not save engineering salaries

Fixed-cost renewables reduce financial risk and provide the basis for reconceptualizing the electricity production/delivery process.
TECHNOLOGIES MATURE BECAUSE THEY EXHAUST EFFICIENCY GAINS.

U.S. Average Efficiency for Base-load Steam–Electric Utility Plants

YET NEW TECHNOLOGY OFTEN DIFFICULT TO JUSTIFY
TRADITIONAL COST APPROACHES NO LONGER WORK: THE CASE OF YAMAZAKI MACHINE

YMAZAKI – FMS Investment: $18 million (circa 1970’s)

- Number of Machines: 68 Reduced to 18
- Order processing time (days): 35 Reduced to 1.5
- Floor Space (sq. ft. × 10^3): 103 Reduced to 30
- Employees (number): 215 Reduced to 12

Project’s Accounting Return Under 10%

Source: Robert Kaplan, “Must CIM be Justified on Faith Alone,” HBR
See: R. Kaplan: "Must CIM be Justified on Faith Alone?" \textit{HBR} / R. Foster, Innovation: Attacker's Advantage
ARE INCREMENTAL PROCESS IMPROVEMENTS IN ELECTRICITY GENERATION & DELIVERY LESS RISKY THAN RADICAL ARCHITECTURAL INNOVATIONS?

- Underestimating the Risks of No-Action or Piecemeal Enhancement (a la R. Kaplan)

The countryside is littered with remains of firms who chose "safe" incremental improvements over what appeared at the time to be "radical" innovations:

- Pickett/K&E; Victor Comptometer,
- U.S. Steel Industry

Moral: i) Calculators seemed radical;
    ii) Mini-mills and continuous casting did not seem cost-effective
THE ROLE OF MARKET RISK IN TECHNOLOGY VALUATION

RISK ADJUSTED

COST-OF-ELECTRICITY ESTIMATES
VALUING ENERGY TECHNOLOGIES NECESSARILY INVOLVES AN ASSESSMENT OF FINANCIAL RISK

- Traditional cost-of-electricity estimates, approaches, yield “rule of thumb” valuations
  - Ignores risk differentials among technologies and processes xx
  - Probably sufficed until very recently xx
  - Ignores the effects of corporate taxes and depreciation tax shelters xx

- Fossil Fuel Prices Vary Systematically

- The costs of Passive/Capital-Intensive Technologies (e.g.: PV, wind) are Essentially Systematically Riskless (beta ≈ 0)
Valuation: Arbitrary Discounting Can Produce Conflicting Results

Valuing Two Bond Investments Using a Single Arbitrary Discount Rate

Assumed Discount = 6%

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<th>Present Value of Proceeds</th>
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10% Junk Bond

4% Government Bond

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### Sensitivity Analysis for Bond Investments With a Single Arbitrary Discount

#### Assumed Discount = 6%

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<td>$1,040</td>
<td>$936</td>
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</table>

**Net Present Value**

- **10% Junk Bond**: $131, $49
- **4% Government Bond**: $(65), $(143)

**Percent Change**

- **10% Junk Bond**: 0%, -62.9%
- **4% Government Bond**: 0%, -118.9%
Ignoring Risk in Valuation:
Present Values Using a Single Discount Rate for all Costs
Decision Outcome is Unaffected for Homogeneous Technologies

Based on NARUC [1990] Costs
Cost and Price for Gas-CC and PV (1996)
Engineering Vs. Risk-adjusted Approaches

Source: Awerbuch, How to Value Renewables, IREC, 1996

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Fossil Fuel Prices Vary Systematically

- Negative covariance with economic activity ($\beta < 0$)
- First observed by Lind and Arrow (Johns Hopkins Press 1986)
- Important implications for EU energy diversity/security goals
  - Fossil price increases seem to depress economic activity
  - More profound implications than traditional "energy security" view
- Important portfolio Implications:
  - Non-fossil generating assets produce counter-cyclical returns
  - Their value is high when the rest of portfolio is low
Fossil-Fuel Prices for Electric-Utility Generating Plant

Source: EIA "Cost and Quantity of Fuels for Electric Utility Plants"

NYS BETAS (1980-1990)
Oil/Gas: -1.1
Coal: -0.25

Oil
GAS
COAL
S&P 500

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A Primer On Risk:

- Modern Finance Theory Based on Risk Research in 1950's
  - Capital Asset Pricing Model for Estimating Market Price of Risk ⇒ Cost of Capital
  - Equivalent to Determining Cost of Any Other Resource

- Total Risk Is the Year-to-Year Variability ($\sigma^2$) in Financial Returns
  - Returns on "safe" assets cluster closely around the mean or expected rate of return
A PRIMER ON RISK-- CONTINUED

• Two Components of Risk:

\[
\text{Total Risk} = \text{Diversifiable Risk} + \text{Systematic Risk} = \sigma^2 \{\text{annual returns}\}
\]

(Random) (Non-Diversifiable)

• Random Risk Does Not Affect the Discount Rate
  - Investors can readily diversify it away
  - Markets do not compensate investors for assuming random risk
    - weather adjustment clauses?

• Markets Compensate Investors for Systematic Risk Only

  - The extent to which the investment's returns co-vary with returns on a diversified portfolio of assets

  Q. Is oil exploration "risky"?
  Q. Is owning a roulette wheel risky? Many wheels?
• Systematic Risk ($\beta$): The Co-Variance of Project Costs (or Returns) with Returns to a Diversified Market Portfolio

\[ \beta_{\text{cost,mkt}} = \frac{\text{Cov}(K_{\text{cost}}, K_{\text{mkt}})}{\sigma_{\text{mkt}}^2} = \frac{\rho_{(\text{cost,mkt})} \cdot \sigma_{\text{cost}} \cdot \sigma_{\text{mkt}}}{\sigma_{\text{mkt}}^2} \]

-- Beta = “Riskiness of the cost (or benefit) stream relative to the market portfolio”
-- Beta for the market as a whole = 1.0 by definition

• Estimating the Appropriate Discount Rate for a Cost (or Benefit) Stream:
  1. Empirically: $K_{\text{cost}} = K_{\text{rf}} + \beta \times (K_{\text{mkt}} - K_{\text{rf}})$
  2. By Convention:
     - Debt-Equivalent Costs -- Discounted at $K_{\text{debt}}$
     - Riskless Costs -- Discounted at $K_{\text{risk-free}}$
Using the CAPM to Estimate Discount Rates for Projects and Cost Streams

\[ Km = \text{Required Return to Diversified Market Portfolio, } (\text{Beta} = 1.0) \]
\[ K_j = \text{Required Return With Beta} = B_j \]
\[ K_c = \text{Required Return With Beta} = B_c \]
A PRIMER ON RISK-- WHAT MAKES FUEL PRICES RISKY?

Gas-Price Forecasts: Two Equally Likely Scenarios: 2% and 4% Growth

Forecast A: 4% Escalation

Forecast B: 2% Escalation

Expected Escalation: 3%
Risky Cash Flows

Figure 1: Risky Revenues and Costs -- Riskless Profits

Years

Dollars

Revenues

Costs

Cash to Investors

Figure 2: Risky Revenues, Riskless Costs -- Risky Profits

Years

Dollars

Revenues

Costs

Cash to Investors

Figure 3: Risky Revenues With Countercyclical Costs

Years

Dollars

Revenues

Costs

Cash to Investors
### Expected Annual Costs for Two Alternative Generating Technologies

Sponsor’s Rate of Return (WACC): 10%

<table>
<thead>
<tr>
<th>Technology A: Costs Vary With Output</th>
<th>Technology B: Fixed Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Outlay</td>
<td>$0</td>
</tr>
<tr>
<td>Project Life</td>
<td>30 years</td>
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<tr>
<td>Expected Revenue:</td>
<td>$115</td>
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<td>E(Variable Maint.) */</td>
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<td>E(Fixed Maint.) */</td>
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<tr>
<td>E(Net Cash Flow)</td>
<td>$ 50</td>
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<tr>
<td>E(Net Cash Flow)</td>
<td>$ 50</td>
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</tbody>
</table>

* Revenues and Variable Maintenance Costs Vary Directly With Output

- Under Traditional Methods:
  PVRR (Project A) = PVRR (Project B) and NPV(A) = NPV(B)

- But…. Are These Projects Valued Equally By Investors?
Panel I: Safe Projects-- Revenues and Costs Move in Unison
(Cash Flow and Project Risk- Cyclical Outflows)
Panel II: Cash Flow and Risk-- Fixed Outflows
Risky Projects -- Revenue and Costs Move Differently

Net Cash Flows

YEARS

INFLOWS

OUTFLOWS

Net Cash Flows
The Relationship of Revenues, Costs and Net Cash Flows

- WACC is the Discount Rate for the Net Cash Flows to Investors
  (Earnings + Depreciation + Interest Payments + Tax Deferrals)

- Technology Valuation—Choosing among two Process Technologies—
  Involves Estimating the Present Value of Revenue Requirements or Costs

- What is the Discount rate for Costs? -- $K_{\text{COST}}$
**Valuing Project Cash-Flow Components**

- The (risky) revenue streams are unaffected by the choice of generating technology
  - Average or expected value = $115

- Standard capital-market theory
  - Investors prefer $A$ over $B$ since: $\text{E}$(return)$_A = \text{E}$(return)$_B$, but risk is lower.

- Now: $\text{PV}(\text{NCF}) = \text{PV}(\text{REVENUES}) - \text{PV}($OUTFLOWS$)$
  
  If: $\text{PV}(\text{REVENUES})$ of $A = \text{PV}(\text{REVENUES})$ of $B$

  and: $\text{PV}(\text{NCF})$ of $A > \text{PV}(\text{NCF})$ of $B$

  Then: $\text{PV}($OUTFLOWS$)$ of $A < \text{PV}($OUTFLOWS$)$ of $B$

- Can hold only if the “safer” outflows of $B$ are discounted at a lower rate
  - Intuitively appealing: makes their PV’s larger, which reduces $\text{PV}(\text{ncf})_B$, as it should, since $B$ is less desirable than $A$.  (Proof : Copeland /Weston [1988, 416]
Valuing Project Cash-Flow Components – Numeric Solution

- Assume: $K_{rf} = 6.0\%$ = the appropriate discount for riskless costs of Project B and the riskless NCF of Project A.

- The risk of the revenues is the same as the risk of a broadly diversified market portfolio (i.e. $\beta = 1.0$), whose return or discount rate is $K_{rev} = 12\%$.

Relationship for Three Discount Rates $K_{cost}$, $K_{net}$ (WACC) and $K_{rev}$ [Booth 1982, JFQA] (two-period model)

\[
\frac{PV_{REV}}{PV_{COSTS}} = K_{COST} = K_{REV} \times \frac{PV_{REV}}{PV_{COSTS}} - K_{NET} \times \frac{PV_{NET}}{PV_{COSTS}}
\]

Rearranging: $K_{cost_A}$:

\[
K_{cost} = .12 \times \left( \frac{934}{246} \right) - .06 \times \left( \frac{688}{246} \right) = 27\%
\]
## Table 4-___

**Estimating The Discount Rate for Outflows (K\text{out}) and Project Value**

\[ K_{\text{rev}} = K_{\text{mkt}} = 12\%; K_{\text{rf}} = 6\% \]

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PROJECT A</th>
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<th>PROJECT B</th>
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<tbody>
<tr>
<td></td>
<td>CYCLICAL OUTFLOWS</td>
<td>INFLOWS</td>
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<td></td>
<td>$109</td>
<td>$65</td>
</tr>
<tr>
<td>29</td>
<td>$113</td>
<td>$63</td>
<td>$50</td>
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<td>$65</td>
</tr>
<tr>
<td>30</td>
<td>$108</td>
<td>$58</td>
<td>$50</td>
<td></td>
<td>$108</td>
<td>$65</td>
</tr>
</tbody>
</table>

**Discount Rate**

- PROJECT A: 12.0%
- PROJECT B: 6.0%

**Present Values**

- PROJECT A: $934
- PROJECT B: $688

\[ PV_{out} = PV_{rev} - PV_{ncf} = 246 \]

\[ PV_{ncf} = PV_{rev} - PV_{out} = 35 \]

**IMPLIED k**

- PROJECT A: 26.9%
- PROJECT B: 139%
$K_i = 12.0\%$
$PV_{in} = $934$
$PV_{out} = $916$
$PV_{net} = $19$
$K_o = 5.7\%$
$K_{net} = 246.0\%$

Panel III: Cash Flow and Risk--Counter-Cyclical Cash Outflows
Highly Risky Projects -- Revenue and Costs Move Opposite
Market Based Cost-of-Electricity Estimates for IEA Europe

- Extends Previous US-DOE Funded Research

- Provides Risk-Adjusted, (Market-Based) C-O-E Estimates

- These Differ from Engineering Estimates
  - Reflect market risk and the effects of taxation
  - Results have an economic interpretation:
    - The cost at which a 30-year contract for future electricity delivery would trade in efficient markets
POST-TAX RISK-ADJUSTED COST-OF-ELECTRICITY ESTIMATES

• Riskier Costs ⇒ Lower Discount Rates ⇒ Higher Present Values

• Reflects the Effect of Taxes and Depreciation Tax Shelters
  -- Effects not uniform across technologies

• Enables “Apples-to-Apples” Comparison
  – Important in today’s environment of heterogeneous technological alternatives

• C-O-E Estimates Can be Interpreted as the cost at which a 30-year contract for electricity delivery would trade in efficient markets
  -- Differs from Engineering COE Estimates
RISK-ADJUSTED VALUATION (DISCOUNTING) PROCEDURES

STEP I. USE EXPECTED COSTS

• Probability-weighted average of all outcomes

• Reflect diversifiable risks ("technology" risks) and contingencies
  – e.g.: turbine or inverter failures, etc.
  – future environmental retrofits
  – These do not affect discount rates

• Diversifiable risks largely included to the extent that WEO cost inputs are based on actual field observations
  – Otherwise – estimate for each technology using: \[ \sum p_j \times c_j \]
**RISK-ADJUSTED DISCOUNTING (CONTINUED)**

**STEP II.** DISCOUNT EACH EXPECTED COST AT ITS (POST-TAX) RISK-ADJUSTED RATE TO PRODUCE PRESENT VALUE COST PER KW

- Four risk-homogeneous cost categories– four discount rates
- Discount rates pertain to the cost stream – not the technology
  - e.g.: The discount for fixed O&M is independent of technology

<table>
<thead>
<tr>
<th>Cost Group</th>
<th>Risk Category</th>
<th>Estimation Procedure</th>
<th>Nominal Pre-Tax Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depreciation tax-shelter</td>
<td>Riskless</td>
<td>Convention</td>
<td>4.3%</td>
</tr>
<tr>
<td>2. Fixed O&amp;M</td>
<td>Debt-Equivalent</td>
<td>Convention</td>
<td>7.4%</td>
</tr>
<tr>
<td>3. Variable O&amp;M</td>
<td>Pro-Cyclical</td>
<td>Judgment</td>
<td>9%</td>
</tr>
<tr>
<td>4. Fuels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fossil</td>
<td>Counter-cyclical</td>
<td>Empirical</td>
<td>0.5% – 4%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>Debt-equivalent</td>
<td>Empirical</td>
<td>7.4%</td>
</tr>
<tr>
<td>Bio</td>
<td>Riskless</td>
<td>Literature</td>
<td>4.3%</td>
</tr>
</tbody>
</table>
STEP III. LEVELIZE PRESENT-VALUE COSTS TO DERIVE LEVELIZED ANNUAL COST PER KWH

- Levelized costs represent an imaginary time-weighted average
  - Cannot be compared to observed market prices

- Widely used, but creates significant problems
  - In the case of arbitrary discounting, levelization can produce conflicting valuation criteria

- Theoretically, the levelization rate will differ for each technology and each year of the project life (J. Read, EPRI, 1991)
  - Represents the rate of return at which investors are indifferent between the lump-sum present value cost and the levelized annual cost
  - Generally the after-tax WACC (given the right assumptions)
  - Presents enormous computational hurdles
A defensible compromise levelization procedure:

- Two levelization rates, one for fossil projects, one for fixed-cost projects
  - Fossil estimate based on Value-Line power producer sample
  - Estimate for fixed-cost technologies based on asset beta = 0.1
    - 10 – 20 times as risky as investment grade corporate bonds

Produces an empirically reassuring risk premium for fossil projects:

- WACC for Fossil Projects: 7.0%
- WACC for Fixed Cost Projects: 5.7% (should be 5.4)
- Implied Fossil Risk Premium: 1.3%

- Fossil fuel risk alone produces a CAPM risk premium of 0.7% - 2.0%
Estimating Discount Rates: Systematic Fossil Price Risk Measured Against the Morgan-Stanley MCSI Europe Stock Index (Based on French & Fama)

Europe Coal Import Prices Vs. MSCI Europe Index

MSCI Europe Stock Index

Steam Coal Import Price IEA-Europe

Shimon Awerbuch, Ph.D.
Fossil Prices Vs. MSCI Europe Stock Index (Continued)
Returns to Europe Import Gas Vs. Returns to MSCI Europe Stock Index
(48-Month Beta = -0.15)
60-MONTH RETURNS TO EUROPE OIL & COAL VS. MSCI INDEX

**Crude Oil Imports (Beta = -0.05)**

- Returns to Imported Crude vs. Europe Index

**European Steam Coal Imports (Beta = -0.45)**

- Fuel Versus Market HPR

Shimon Awerbuch, Ph.D.
SYSTEMATIC RISK OVER TIME -- COAL AND CRUDE

Crude Oil Betas Over Time

Coal Cash-Flow Betas Over Time
Quarter Average Lagged

Shimon Awerbuch, Ph.D.
Returns to Europe Import Gas Vs. Returns to MSCI Europe Stock Index (48-Month Beta = -0.15)
TOTAL FOSSIL FUEL RISK OVER TIME

Fossil Fuel Price Variability Over Time
Coefficient of Variation (Sigma/Mean) of Yearly Data

SD of S&P 500
Fossil Correlations Over time:
The Gas-Coal Portfolio Offers Little Opportunity for Diversification

Europe Fossil Correlation Coefficients

- Oil-Coal
- Oil-Gas
- Gas-Coal

Correlation Coefficient

Risk-Adjusted Cost-of-Electricity Estimates: "Historic Fuel Price Risk"

Levelized Market-Based Electricity Cost and Price Estimates
- Historic Fuel Price Risk -

Traditional | Price | Cost

Coal Boiler | Coal IGCC | Gas CC | Gas GT | Nuclear | BIO | HYDRO conv | WIND | SOLAR Thermal | GEO | PV | PV Max Insol.
Risk-Adjusted Cost-of-Electricity Estimates: "No-Cost" Contract Fuel

Levelized Market-Based Electricity Cost and Price Estimates
30-Year "No-Cost" Contract Fuel Assumption
TRADITIONAL VALUATION ALSO DISTORTS ENVIRONMENTAL ISSUES

Capacity and Externality Costs Per kW

- First Year Externality Cost: $0.05/kWh
- Capacity Factor: 55%
- SRTP: 3.0%
- WACC: 9.4%

Initial Capacity Cost
WACC-Based Present Value
Societal Present Value
Valuing Externalities: Quasi-Perpetual Annual Emissions

\[ g = \text{Real Rate of Growth in the Economy (\( \Delta \) Population \( \cdot \) \( \Delta \) Income)} \]
\[ = \text{Rate of Growth in the Value of Environmental Damage} \]
\[ \text{Caused by Constant Emissions Level} \]

\[ k_s = g = \text{Social Rate of Time Preference} \]

\[ E_1 = \text{First Year Externality Cost}; \]
\[ E_t = E_1(1+g)^t \quad t = 1, n \]

Present Value of Environmental Costs =
PV[Perpetuity With Growth] \( \Rightarrow \) Gordon Growth Model

\[ \text{Present Value of Environmental Cost} = E_1 / (k_s - g) = \infty \]
Valuing Externalities:
Case II: Finite-Lived Project, Constant Annual Emissions

g = Real Rate of Growth in the Economy
   = Rate of Growth in the Value of Environmental Damage
ks = g = Social Rate of Time Preference

E₁ = First Year Externality Cost;
Eₜ = E₁(1+g)ᵗ \hspace{1cm} t = 1,n

\[ PV = \sum_{t=1}^{n} \frac{E₁(1+g)ᵗ}{(1+ks)ᵗ} = n\cdot E₁ \]

*Present Value of Environmental Costs = First Year Cost \times Project Life*
FURTHER MEASUREMENT ISSUES:

PROBLEMS OF ELECTRICITY COST LEVELIZATION

VINTAGE – LEVELIZED COSTS
Levelized COE Estimates cannot be compared to actual market prices.

Actual Prices Versus Levelized Charges

Projected Fossil Electricity Cost

Projected Cost of Renewables-Based Electricity (Current-Vintage Technology, Levelized Capital Recovery)

Levelized Fossil Electricity Cost

Year 1 Fossil Electricity Cost

YEAR

$0.00 $0.05 $0.10 $0.15 $0.20 $0.25 $0.30

$0.00 $0.05 $0.10 $0.15 $0.20 $0.25 $0.30

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Levelized Costs Mask Important Inter-Temporal Information

Levelized Costs Can Be Misleading
Direct Projected and Levelized Costs

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CMU slides - dist-set-notoons.doc - 11/04/02
LEVELIZED COSTS MASK IMPORTANT INTER-TEMPORAL INFORMATION

Comparing Gas and PV Using Certainty Equivalents
Projected Levelized and Re-Scheduled Costs

Year

PV-Levelized

PV Rescheduled

GAS Certainty Equivalent

Gas-Projected

Gas-Levelized

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CAN WE ALTER OUR COMPACT WITH FUTURE GENERATIONS?
RENEWABLES CAN RESHAPE THE LEGACY WE LEAVE FOR THEM

- Fossil Fuel Usage Saddles Future Cohorts With Rising Fuel and Environmental Costs

- Should We Alter Our Compact With Future Generations?

It may be no greater injustice to install renewables now and shift capital recovery to future generations!
WE MUST VALUE ENERGY STRATEGIES -- NOT TECHNOLOGIES

Vintage-Levelized Costs of PV: Equal Dollar-Outlay Vintages (e=-1.0)
Proxy European Tax Structure and 10% ETC

Year 1 Cost: $5,200/kW;
Technological Progress: .0685/Year

$-Vintage-Levelized Cost
ACCOUNTING MEASUREMENT, INNOVATION,
ORGANIZATIONAL CHANGE AND OTHER ISSUES

SHIMON AWERBUCH
Understanding and Valuing Distributed RETs: The Role of Organizational and Infra-structure Changes

• RETs/DG: First Reorganization Around New Technology in 100 years
  — Cannot be understood in context of current (19th Century) utility Organizations
  — Existing T&D Networks, PEx, ISO structures, AGC, etc. -- all developed in support of large-scale central generation
    • do not support RETs

• Fully Exploiting RETs will require Infra-structure changes
  – “Informated” T&D Networks
  – Smart Meters
  – Discreet Load Matching – intermittent resources and loads
  – Decentralized network operation – no centralized AGC
Understanding and Valuing Distributed RETs: 
The Role of Organizational and Infra-structure Changes

• Example: Reorganization –Bessemer Steel and Word Processing Both Required Organizational and infra-structure changes
  — Bessemer: US- Reorganization, floor-plan, upstream & downstream flow-control quadruples productivity (Clark)
  — Word Processor: just a new typewriter - give it to the typing pool
    — exploitation required major organizational, (disintermediation) and value changes

• Learning How to Fully Exploit Renewables is Non-Trivial

  Renewables are as much a substitute for fossil plants as computers were a “substitute” for typewriters & calculators
## The Role of Quality in Electricity Generation and Delivery

<table>
<thead>
<tr>
<th>Manufactured Products</th>
<th>Electricity</th>
</tr>
</thead>
</table>
| - Lower energy & labor content  
- Higher information-content  
- More value to customer  
(P. Drucker) | Fewer kWh's with higher information content and greater value:  
“Fewer, Smarter kWh’s” |
| From Mass-production to Flexible, just-in-time Manufacturing and Mass Customization | - Lower Overhead DG/RE  
- Virtual utilities  
- Decentralized networks to facilitate market-based transactions  
- Minimizing transactions costs, excess generation and reserve capacity |

Mechanical Vs. Cognitive Paradigms: The New Information Economics

- Mechanical Production Paradigm:

  Raw Materials $\rightarrow$ Production $\rightarrow$ Output

  Efficiency (Mechanical) = Input/Output

  — e.g.: Btu / kWh, $ / kWh, € / km driven
Mechanical Vs. Cognitive Paradigms: The New Information Economics

- Cognitive Production Paradigm—The Information Age:

  Data → Information/Decisions → Action

  -- Mechanical-age measures & decision tools do not work

  -- Information-age firm is a decision-factory
    - Design for quality decisions
    - Decision quality = 
      \[ f (\text{data availability, processing speed, asset reconfiguration/deployment}) \]
    e.g.: steel mini mills, Williams/Cat mobile turbines
VALUING RENEWABLES AS A RADICAL ARCHITECTURAL INNOVATION — WHAT IT REQUIRES

- Integration of Modern Valuation Theory & Development of New Accounting Concepts, Insights and Valuation Measures
- Beyond Direct Costs- A Search for Complementary Benefits
  -- Overhead Reductions, Information-Based Capabilities
- Avoiding Myopic “Shoehorn” Analyses
  -- Full Exploitation Involves Organizational Learning and infra-structure changes

“The amazing historic stability of key relationships depletes our capacity to imagine anything different... “ Bernstein, HBR

“The New Religion of Risk Management”
Synopsis: A Richer Accounting Vocabulary: Beyond Direct Cost Reduction

- Today’s Cost & Value Measures Conceived in Context of 19th Century Organizations and Technology
  
  -- New Cost & Value Concepts Were Needed to Understand “New Manufacturing” -- Quality, Capability & Flexibility Options & ABC
  
  -- RETs are conceptualized using cost ideas developed for steam plants

  “$/kWh” is About as Useful for Comparing PV to Gas-Fired Turbines as “$/Mile” is for Comparing Automobiles to Horse-Drawn Carriages;
The Moral

1. Fully Understanding RE/DG and Other New Technologies Requires:

   a) The integration of modern portfolio based financial valuation models

   b) The development of new accounting concepts and valuation insights and measures;

2. Trying to understand passive RE/DG using today’s accounting vocabulary is roughly equivalent to trying to appreciate Shakespeare by 'listening' to a Morse-code rendition of Hamlet.
Illustration: Accounting vs. Economic Rates of Return

Depreciation, Firm Reinvestment and Firm Growth

Initial Principal Outlay $1,000
Investment Life 5 Years

Annual Revenues $298.32
Operating Expenses $0.00
Net Cash Flow $298.32
Rate of Return 15.0%

"Proof": Present Value of {($298.32 / 5 years / 15%) = $1000}
## Accounting and Economic Rates of Return

5-Year Asset With No Operating Expenses -- IRR = 15%

<table>
<thead>
<tr>
<th>Yr</th>
<th>Revenue</th>
<th>Depreciation</th>
<th>Net Income</th>
<th>Opening Book Value</th>
<th>ARR (ROE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$298.32</td>
<td>$200.00</td>
<td>$98.32</td>
<td>$1,000.00</td>
<td>9.8%</td>
</tr>
<tr>
<td>2</td>
<td>298.32</td>
<td>200.00</td>
<td>98.32</td>
<td>800.00</td>
<td>12.3%</td>
</tr>
<tr>
<td>3</td>
<td>298.32</td>
<td>200.00</td>
<td>98.32</td>
<td>600.00</td>
<td>16.4%</td>
</tr>
<tr>
<td>4</td>
<td>298.32</td>
<td>200.00</td>
<td>98.32</td>
<td>400.00</td>
<td>24.6%</td>
</tr>
<tr>
<td>5</td>
<td>298.32</td>
<td>200.00</td>
<td>98.32</td>
<td>200.00</td>
<td>49.2%</td>
</tr>
</tbody>
</table>

$1,000.00

**Average:** 22.4%

### Panel I: Straight Line Depreciation

### Panel II: Economic (Annuity) Depreciation

<table>
<thead>
<tr>
<th>Yr</th>
<th>Revenue</th>
<th>Depreciation</th>
<th>Net Income</th>
<th>Opening Book Value</th>
<th>ARR (ROE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$298.32</td>
<td>$148.32</td>
<td>$150.00</td>
<td>$1,000.00</td>
<td>15%</td>
</tr>
<tr>
<td>2</td>
<td>298.32</td>
<td>170.56</td>
<td>127.75</td>
<td>851.68</td>
<td>15%</td>
</tr>
<tr>
<td>3</td>
<td>298.32</td>
<td>196.15</td>
<td>102.17</td>
<td>681.12</td>
<td>15%</td>
</tr>
<tr>
<td>4</td>
<td>298.32</td>
<td>225.57</td>
<td>72.75</td>
<td>484.97</td>
<td>15%</td>
</tr>
<tr>
<td>5</td>
<td>298.32</td>
<td>259.40</td>
<td>38.91</td>
<td>259.40</td>
<td>15%</td>
</tr>
</tbody>
</table>

$1,000.00

**PV=$1,000.00**
## Hick's Income and the Amount the Owners Can Safely Withdraw

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Cash Flow</th>
<th>Distributable (Hick's) Net Income</th>
<th>Resulting Retention (Depreciation)</th>
<th>Future Compounded Retention Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>($1,000.00)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>$298.32</td>
<td>$150.00</td>
<td>$148.32</td>
<td>$259.40</td>
</tr>
<tr>
<td>2</td>
<td>298.32</td>
<td>150.00</td>
<td>148.32</td>
<td>225.57</td>
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<td>3</td>
<td>298.32</td>
<td>150.00</td>
<td>148.32</td>
<td>196.15</td>
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<tr>
<td>4</td>
<td>298.32</td>
<td>150.00</td>
<td>148.32</td>
<td>170.56</td>
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<tr>
<td>5</td>
<td>298.32</td>
<td>150.00</td>
<td>148.32</td>
<td>148.32</td>
</tr>
</tbody>
</table>

|       |           | $1,000.00                        |                                    | $1,000.00                        | (Sinking Fund)                     |

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