Integrated Resource Planning

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Frederick Weston
Purpose of IRP

➢ To meet demand for energy services at the least cost to society, including environmental costs
Least-Cost Integrated Resource Planning

- Energy resources optimized to meet forecast demand
- Reduce total system costs
- Uses demand-side resources as well as supply-side resources
- Objective is lowest (total) cost energy services
- Maximize benefit for total $ spent
Least-Cost Integrated Resource Planning

- Reduces volatility of demand
- Enhances reliability
- Reduces the need for large-scale capital construction
- Reduces environmental impacts
Least-Cost Integrated Resource Planning

- A change in the way the electric system is planned and built
- A recognition of the economic component of the resource acquisition process
- **Need** is an economic concept, not simply an engineering one
Load Forecast

Identify Goals

Existing Resources

Need for New Resources

Supply
Demand
T&D
Rates

Optimize Resource Mixes

Uncertainty Analysis

Public Review/ PUC Approval

Monitor

Acquire Resources

Action Plans
Elements of IRP

- Define planning objectives
- Define planning period
- Forecast demand
- Identify resource options
- Optimize resources to meet IRP objective
- Long-term plan/Action plan
- Public participation
- Implementation
- Build from bottom up
- End use forecasts
  - Building stock
  - Appliance stock, standards
  - Energy intensity
  - Self-generation
- Load losses pose serious problem
- Price elasticity feedback
Identify Resource Options

- Supply side

- Demand side
Supply-side Options
Examples

- Conventional plants
  - Large fossil-fueled
  - Nuclear
  - Small combustion turbines
  - Life extensions of existing plant
  - Transmission expansion or upgrade
  - Reduced transmission losses
  - Advanced transformers
Supply-side Options

Examples

- Non-utility owned generation
  - Cogeneration
  - Small-scale hydro
  - Self-generation
  - Independent power producers

- Purchases
  - Requirements transactions
  - Coordination transactions
Supply-side Options

Examples

- Renewables
  - Geothermal
  - Solar
  - Wind
Demand-side Options

Examples

➢ Energy-efficiency options (customer)
   - Home weatherization
   - Energy-efficient appliances and lighting
   - High-efficiency heating, ventilating and air conditioning
   - Load management
   - Utility control of appliances
   - Manufacturing process improvements

➢ Passive solar modifications
Rate Design Options

- Time of use
- Interruptible
- Incentive
Cost of Options

- Life cycle costs
- Fixed costs vs. variable costs
- Environmental and other externalities
- Other attributes
  - Fuel diversity
  - Technological and other risks
  - Fuel cost uncertainty
Different interests have different economic criteria

- Consumers
- Utilities
- Society

Different interests see different costs and benefits

Therefore, multiple perspectives for determining cost-effectiveness
Cost Effectiveness Tests

- Participant test
- Rate impact test (non participant, no losers test)
- Utility (revenue requirements) test
- Total resource cost (all ratepayers) test
- Societal test
Optimize Resources

- Find the mix of resources that minimizes the total cost of energy services
- Judgment and modeling
- Iterative process
- Uncertainty analysis - consider sensitivities; least-cost is low cost for a wide range of plausible scenarios
Public Participation

- Technical workshops
- Collaboratives
- Public hearings
Utility Participation

- New corporate skills
  - Integrated analysis
  - Demand-side program design and implementation
  - Analysis of external costs
  - Marketing operation and maintenance of different facilities
  - Organizational changes
Align Utility's Interest to IRP

- Internal incentives which match new IRP paradigm
  - Salary
  - Promotions

- External incentives
  - Profit
  - Public recognition
Policy Decisions for the Commission

- What is the IRP objective
- How can market forces be used in the IRP process
- How can regulation harmonize the interests of ratepayers and shareholders
- Should the commission approve utility IRPs
- How can the commission build an effective process
GSTD +/- gs
Planning Models

➢ Optimization Models
  - UPLAN
  - PROMOD

➢ Financial Models
  - ELFIN
  - UPLAN
  - @RISK

➢ Forecasting Models
  - REMI
  - Energy 20/20
IRP and Competition

- The goal of IRP is to reduce costs
- Competition is a means to help get us there
- IRP is needed to tell you who wins
- The more diverse the resources, the more you need IRP
History

- Natural outgrowth of IRP
- First bidding in 1984 resulting from supply exceeding demand
- Bidding is now common practice
- Many lessons learned along the way
- End result - very positive
### U.S. Bidding Experience

<table>
<thead>
<tr>
<th></th>
<th>Supply</th>
<th>Demand</th>
</tr>
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<tbody>
<tr>
<td>RPSs</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>164</td>
<td>111</td>
</tr>
<tr>
<td>MWs Requested</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply</td>
<td>42,849</td>
<td></td>
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<tr>
<td>Demand</td>
<td>33,555</td>
<td></td>
</tr>
<tr>
<td>MWs Bid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply</td>
<td>467,000</td>
<td></td>
</tr>
<tr>
<td>Demand</td>
<td>3,757</td>
<td></td>
</tr>
<tr>
<td>MWs on-line</td>
<td></td>
<td></td>
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<tr>
<td>Supply</td>
<td>8,752</td>
<td></td>
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<tr>
<td>Demand</td>
<td>148</td>
<td></td>
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<tr>
<td>States using bidding</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>37</td>
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</table>
Competitive Bidding

- Further expanded options
- Lower costs for similar resources
- Innovative contracting
  - Options
  - Operational flexibility
Avoided Cost
Avoided Cost Analysis is Key to Optimal Integration

- A new resource should be added whenever it is cheaper than the existing or planned resource it displaces.

- Each hour in each year has its own avoided cost.

- The value of a new resource is determined by what it displaces.
You get a 5-cent bid and a 6-cent bid

- Who wins?
- What is your avoided cost?
What is the Product?

**EQS**
- How dispatchable
- What is min load, ramp rate, startup cost
- What is forced outage rate
- How long are scheduled outages/can util schedule
- What is contract duration
- Where is plant located
- How does plant impact required reserve margins

**HQS**
- Pricing terms
- Impact of resource options on fuel diversity
- Security and perform. terms
- Provisions for contingency, buy-out, deferral and cancel.
- Developers' experience
- Specific price and risk allocations
- Buyer's risk
- Future environmental regs cost
What if the 5-cent bid is worth 4 cents and the 6-cent bid is worth 7 cents?

- 5-cent bid costs more than AC
- 6-cent bid costs less than AC
- Avoided cost is ???????
### Answers

<table>
<thead>
<tr>
<th>Who wins</th>
<th>can't tell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided Cost</td>
<td>can't tell</td>
</tr>
<tr>
<td>How do we tell?</td>
<td>IRP, bid evaluation</td>
</tr>
<tr>
<td>Non Price</td>
<td>Sure - but utility and customers may differ</td>
</tr>
</tbody>
</table>
Avoided Cost Definition

What is the greatest amount a society should be willingly to have its utility pay for a resource?
Planning Models

- Designed to analyze, firm conventional resources
- Renewables such as biomass and hydro are simple but reliability often missed (NEPOOL, PJM)
- The models do not easily analyze
  - Intermittent resources
  - Uncertainty/risk
  - Relative environmental impacts
  - Distributed benefits
Two Types of Avoided Cost

- Generic avoided costs, based on an arbitrary standardized resource
- Customized avoided costs, based on specific characteristics of an actual resource
- NOT simply the cost of next plant
Components of Total Avoided Costs

- Avoided generation costs including fixed, variable, and reliability costs
- Avoided line loss costs
- Avoided T&D costs
- Avoided direct environmental costs
- Avoided direct economic costs
- Avoided indirect economic costs
- Avoided administrative and OH costs
Major Steps in Avoided Cost Analysis

- Compile full list of alternative resources
  - Supply side
  - Demand side
- Develop and cost out alternative plans
- Optimize / Choose best plant
### Simple Example -- Two Options

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Annualized Capital Cost</th>
<th>Fuel Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>$1000/KW</td>
<td>$200/KW</td>
<td>$.02/kWh</td>
</tr>
<tr>
<td>#2</td>
<td>$500/KW</td>
<td>$100/KW</td>
<td>$.06/kWh</td>
</tr>
</tbody>
</table>

How much of each do we want?
Cost of Options

By Hours of Operation

Cost ($)

Hours of Operation

Option A

Option B
Load Duration Curve and Resource Acquisition

Load & Capacity

Hours of Operation
Base Plan

- 800 MW of Option A
- 200 MW of Option B
- Total Cost = $303.9 million
Decrement #1

- 50 MW less in every hour

Plan #1
- 750 MW of Option A
- 200 MW of Option B

Total Cost = $285.1 million
Avoided Cost = $303.9 - 285.1 = $18.8 million, or 4.3 cents/kWh
Load Duration Curve and Resource Acquisition

Load & Capacity

Base
800 MW

Decrement
750 MW

Decrement Case

Hours of Operation

Base Case

Decrement #1
Decrement #2

- 50 MW less on peak
- No change in lowest load

Plan #2
- 764 MW of Option A (36 less)
- 186 MW of Option B (14 less)

Total Cost = $290.2 million
Avoided Cost = $303.9 - 290.2 = $13.7 million, or 6.3 cents/kWh
Load Duration Curve and Resource Acquisition

Load & Capacity

Base Case
800 MW

Decrement
#2

Decrement
764 MW

Hours of Operation
Common Mistake #1

➤ The avoided cost is ___ cents per kWh
  - Avoided costs vary year by year
  - Avoided costs vary within any given year

➤ Examples
  - Base load vs. peaking resources
  - Dispatchable vs. non-dispatchable sources
  - Intermittent sources
  - Location on T&D system
  - Reliability effects
Common Mistake #1 (cont'd.)

- Conclusion

  - Every resource has its own "customized" avoided cost

  - No two resources will have the same avoided cost.
Common Mistake #2

Surplus Capacity means avoided costs are zero

- There are always avoided Fuel Costs
- Often avoided transmission and distribution costs
- Once surplus is gone, avoided generation capacity costs will occur
- The risk profile is lopsided
Cost, Worth, and Need

➤ Bids, bus bar cost, etc.:
  - Tells you what a resource costs

➤ IRP, avoided cost:
  - Tells you what a resource is worth

➤ Need:
  - Any resource that costs less than it is worth
Common Mistake #3

➢ There are no Avoided T&D Costs
  ➢ Line losses
  ➢ T&D capacity Costs
    • Distributed Benefits
    • Targeting resources to areas which would otherwise need T&D upgrades
Avoided T&D System Costs

- Construction costs
- Licensing costs
- Operation costs (fixed and variable)
- Maintenance costs (f & v)

Note: Marginal losses can be two, four or more times average losses and transmission can be very expensive
Common Mistake #4

- Intermittent resources have no capacity value
  Question: Do intermittent loads e.g. water heaters, create capacity costs?
  Answer: yes

- Then intermittent supply has capacity value. The question is how much and whether RTP and other capacity options are least-cost
Wind Plant Output
During PG&E Peak Load Days

Output/maximum output

Hour ending (PDT)

Solano 1987

Solano 1988

Altamont 1987

Altamont 1988

Hour of peak PG&E system load

0 0 1 1

0 0 1 1

0 0 1 1

0 0 1 1

Altamont 14

Altamont 16
Common Mistake #5

- A "proxy" plant can be used to accurately calculate avoided costs.

- Typically, the difference between the two optimal resource plants will be attributable to delays in a series of new generating units as well as to changes in the mix of new baseload, cycling and peaking units.
Common Mistake #6

- Goals = Constraints
- Ownership of resources
- Supply-side only
- Dispatchability
- Exposure to individual risks, e.g. fuel supply
Avoided Direct Environmental Costs

- Three components
  - Costs of emissions allowances
  - Costs of pollution control retrofits
  - Cost of compliance with probable future environmental requirements
Avoided Environmental External Costs

- Avoided costs of damages that would potentially be inflicted on the environment as a result of:
  - construction of energy facilities
  - extraction, processing, transport, combustion and disposal of waste and spent fuels
  - consumption of electricity at the point of end-use
  - land and water impacts
Judgment is Unavoidable

- Part policy and judgment, part analytics
- Policy and judgment are important because:
  - many important considerations are too difficult to quantify
  - utility risk assessment may differ from consumer's perspective
Qualitative Aspects

- Diversity
- Oil dependence
- Risk
- Price volatility
- Environment (can be quantitative)
- Tourism
- Economic Development
- Exporting
- $
Market Risk for Renewable Resources
What are the Typical Risks?

- **Resource Level**
  - Cost
  - Performance
  - Permitting/Lead time

- **System Level**
  - Fuel Costs
  - Load Growth
  - Technological Change
  - Environmental
  - Regulatory/Market Structure
Analytical Tools

- Sensitivity (and Scenario) Analysis
- Risk Adjusted Discount Rates
- Options Theory
- Decision Tree Analysis
One Minor Problem

- Need to know:
  - Range of possible values for each risk
  - The likelihood of each value
  - The interactions among them
  - Implications of risk allocation

- History shows we don't do that very well
Fuel Example

- Avoided costs are heavily influenced by oil price forecasts
- **Bad Option**: Tie contract payments to actual oil prices
- **Better Option**: Fix prices based on today's forecast
- **Best Option**: Option 2 plus use market to firm long-term oil price and place fuel risk on utility
# Economic Impacts

## IMPACT OF BIOMASS INDUSTRY ON MAINE ECONOMY

<table>
<thead>
<tr>
<th>Capital investment</th>
<th>$1 billion plus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>1,800-3,300</td>
</tr>
<tr>
<td>GSP</td>
<td>$120-220 million</td>
</tr>
</tbody>
</table>
What is fuel price certainty worth?

- Natural Gas Fixed-Price Contract
- Natural Gas Spot-Prices
<table>
<thead>
<tr>
<th></th>
<th>Projected Spot-Prices</th>
<th>Fixed-Price Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Results:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WACC-Based Value</td>
<td>$388.0 millions</td>
<td>$465.6</td>
</tr>
<tr>
<td><strong>Risk-Adjusted Results:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market-Based Value</td>
<td>$1,260.2</td>
<td>$1,072.3</td>
</tr>
</tbody>
</table>
Risk-Reduction
Benefits of Renewables

- Modularity, environmental, no or low fuel cost uncertainty, resource diversity, use of indigenous energy resources, national energy security issues
Renewable and Risk Analysis

➢ The planning tools were not designed with renewables in mind
➢ Quantifying the direct value of renewables can be improved
➢ Many of the most beneficial aspects of renewables require judgment more than analytics
Conclusions

- No established methodology for considering risk
  - Subjective judgment required
  - More elaborate models tend to obscure, not replace, the subjectivity
Cost Effectiveness Tests

- Participant test
- Rate impact test (non participant, no losers test)
- Utility (revenue requirements) test
- Total resource cost (all ratepayers) test
- Societal test
Participant Test

Purpose: ensure that consumers will want to participate

Are the economics sufficient to induce participation?

Counts direct economic benefits received by participants

Counts only costs incurred and borne by participants
Rate Impact Measure Test

- Purpose: measure impacts on non-participating ratepayers

- Minimizes electricity prices - but will increase overall cost of energy services

- Benefits: utility avoided costs

- Costs: program costs and lost revenues

- Most restrictive test: program is cost effective only if it reduces rev. requirement.
Utility Cost Test

- **Purpose:** measure the change in cost to utility (revenue requirements)

- **Easiest test to meet; most similar to a supply side test**

- **Assumes that regulators will keep the utility whole** (ignores lost revenues)

- **Benefits:** utility avoided costs

- **Costs:** program costs (participant costs ignored)
Total Resource Cost Test

Purpose: measures the change in the average cost of energy services across all ratepayers

Minimizes total cost of energy services, but will increase the price per kWh

Benefits: utility avoided costs

Costs: program costs, participant direct costs
Societal Cost Test

- Purpose: incorporate externalities into analysis

- Like TRC, it ignores allocation of costs and benefits

- Unlike TRC, it draws the boundary of analysis more broadly, around society as a whole
## Cost and benefits

### Economic perspective

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided costs</td>
<td>Program Costs</td>
</tr>
<tr>
<td>Customer bill savings</td>
<td>Customer Costs</td>
</tr>
<tr>
<td>Incentive payments</td>
<td>Lost Revenue</td>
</tr>
</tbody>
</table>

#### Participant test

<table>
<thead>
<tr>
<th>Economic perspective</th>
<th>Benefits</th>
<th>Costs</th>
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</thead>
<tbody>
<tr>
<td>Participant test</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Rate test</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Utility test</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Total resource cost test</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Societal test</td>
<td>X*</td>
<td>X</td>
</tr>
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</table>

*plus avoided environmental costs
Commercial Lighting
Program Example

Costs

Program costs (planning and design, admin customer incentives, evaluation)
Customer costs (their share of measures costs)
Lost revenue

Benefits

Customer bill savings
Avoided costs
Avoided environmental externalities (10% of AC)
## Commercial Lighting
### Program Example

#### Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program costs (planning and design, admin, customer incentives, evaluation)</td>
<td>10.0</td>
</tr>
<tr>
<td>Customer costs (their share of measures costs)</td>
<td>4.0</td>
</tr>
<tr>
<td>Lost revenue</td>
<td>44.0</td>
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#### Benefits

<table>
<thead>
<tr>
<th>Description</th>
<th>Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer bill savings</td>
<td>44.0</td>
</tr>
<tr>
<td>Avoided costs</td>
<td>28.0</td>
</tr>
<tr>
<td>Avoided environmental externalities (10% of AC)</td>
<td>3.0</td>
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### Commercial Lighting Program Example (cont.)

<table>
<thead>
<tr>
<th>Economic Perspectives</th>
<th>PV Costs</th>
<th>PV Benefits</th>
<th>NPV</th>
<th>B/C</th>
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<tbody>
<tr>
<td>Participants</td>
<td>-4</td>
<td>+44</td>
<td>+40</td>
<td>11.0</td>
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<tr>
<td>Ratepayers</td>
<td>-54</td>
<td>+28</td>
<td>-26</td>
<td>0.5</td>
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<tr>
<td>Utility</td>
<td>-10</td>
<td>+28</td>
<td>+18</td>
<td>2.8</td>
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<tr>
<td>TRC</td>
<td>-14</td>
<td>+28</td>
<td>+14</td>
<td>2.0</td>
</tr>
<tr>
<td>Society</td>
<td>-14</td>
<td>+31</td>
<td>+17</td>
<td>2.2</td>
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Energy Efficiency Potential

Source: EPRI CU-6746 (1990)
Potential Savings - by Sector

LOW SCENARIO

8.5%*

HIGH SCENARIO

13.6%*

*percent of total use, year 2000
Residential Savings - by End Use

- Space heat
- Misc. appliances
- Refrigeration
- Cooking
- Central a/c
- Dishwasher
- Water heat
- Room a/c
Residential Programs

- Low-cost measures
direct installation
- Home weatherization financing
- Low-income weatherization grants
- New construction standards*
- Manufactured housing incentives*
- Water heating efficient equipment
- Air conditioner rebates
- Used refrigerator buy-back, recycling
- Compact fluorescent incentives
Commercial Savings - by End Use

- Lighting
- Refrigeration
- Water Heat
- Cooking
- Ventilation
- Heating
- Misc.

Cooling
Commercial Programs

- Efficient lighting incentives (C/I)
- New construction design assistance*
- New construction building commissioning*
- Existing buildings recommissioning
- HVAC replacement rebates*
- Small commercial direct installation
Industrial Savings - by End Use

Motor drives

Lighting

Process heat

Electrolytics
Industrial Programs

- High efficiency motors (C/I)*
- Custom process improvement incentives*
Cost-effective Savings

Energy Savings Potential

- Energy Savings Potential
- Technical 2000
- Cost effective

High Scenario
Low Scenario

Percent

Technical 2000
Customer acceptance

Cost effective
1991 DSM Reduction in Total Energy

- BPA
- WEPCo
- PG&E
- Mass Elec
- SMUD
- Puget

Source: Hirst, ORNL/CON-364 (1993)
DSM Programs are Adaptable

- Avoided costs
- Economic cycles
- Energy deficit or surplus
- Competition for customers
Source: Geller, et al., ACEEE (1992)

Jobs added = 1.1 million in 2010
Conclusions

- DSM potential is large
- Opportunities exist in all sectors
- Market barriers must be overcome
- DSM is adaptable to different situations
Environmental Issues
Overview

➢ Environmental impacts of different fuels/technologies
➢ Environmental pollutants
➢ Methods of environmental regulation
➢ Special problems
Environmental Impacts of Different Fuels/Technologie

- Coal
- Oil
- Natural gas
- Nuclear
- Renewables
  - wind
  - hydro
  - biomass
  - PV
- Demand-side management
Environmental Pollutants

- Air
  - NOx
  - SOx
  - Particulates
  - Greenhouse gases

- Water
- Solid waste
- Radioactive wastes
Methods of Environmental Regulation

- Health-based environmental standards for regions
- Plant-specific controls: end of the pipe emissions and technology
- Pollution prevention
- Environmental externality adders/values (avoided cost)
- Emissions trading and offsets
Special Problems

- Siting issues/politics
- Lender requirements
- Pollution control costs: old plants versus new plants
- Joint implementation
- Environmental comparability
Where IRP Intersects

- Resource cost assumptions
- Fuel cost assumptions
- Load forecast assumptions
Resource Need Decisions

- Prudence
  - Supply and demand
- Siting
- Certificate of need
- Transmission construction
Basic Principles

- Correct pricing of electricity is important
- Rate design process can be improved by aligning rate design with IRP
- Alignment can contribute to the success of a utility's IRP