SOUTHERN CALIFORNIA EDISON®

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Waste Heat-To-Power Generation Workshop University of California, Irvine

Southern California Edison

Business Customer Division

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Presentation Objectives

- Waste Heat-To-Power Generation Project Objectives:
  - Waste Heat-To-Power generation technologies
  - Waste Heat sources and potential power generation opportunities
  - Waste Heat-To-Power generation economics
    - Customer perspective -RFP
    - Electric utility perspective -RFP

Presentation Objectives

- Waste Heat-To-Power Generation Project Objectives (continued)
  - Recovery and utilization of waste heat for electric power generation (conversion of energy into electrical energy) with application of energy conversion technologies
  - Practical conversion of waste heat energy into electrical energy in an economical manner

Waste Heat-To-Power Generation Technologies

- Use of “Heat Engines” – Energy conversion efficiency dictated by laws of thermodynamics; heat engine efficiency is limited by difference in the temperature of the heat source and heat sink. Rankine cycle efficiency can range from 10-36%
- In lower temperature heat recovery applications, considerable attention must be paid to major heat transfer and conversion components. The low thermodynamic quality of heat source requires large heat exchangers, which add to the cost of power conversion systems. The aerodynamic and mechanical efficiencies of the power conversion machinery should be high so that maximum power is realized at a reasonable cost

Waste Heat Sources & Potential Power Generation Opportunities

- Industrial & Process Plants
  - Petrochemical, cement, glass, pulp & paper, metals, mineral processing
    - Process streams containing waste heat
      - Liquids (> 200 degrees Fahrenheit)
      - Gases (> 375 degrees Fahrenheit)
      - Low pressure (LP) steam
      - Condensable vapors
    - Combustion gases
      - Combustion turbine/internal combustion engine exhaust
      - Furnaces
      - Gas pipeline compressor stations
      - Gas processing plants
      - Cogeneration (CHP)
    - Incinerators
      - Thermal oxidizers
      - Flares
      - Biomass/municipal waste gases

Waste Heat-To-Power Generation Workshop

Waste Heat Sources

Industrial Processes
200 deg. F – 400 deg. F

Geothermal (200 deg F – 650 deg F)

Industrial Stack Gases (300 deg F – 800 deg F)

Diesel Exhaust (500 deg F – 900 deg F)

Gas Turbine Exhaust (600 deg. F – 1,000 deg. F)

Metal & Glass Industry (700 deg. F -1,000 deg. F)

Waste-to-Power Gen

Organic Rankine Cycle
(200 deg. F – 400 deg. F)

Binary Cycle (Steam/Refrigerant)
(400 deg. F – 700 Deg. F)

Waste Heat Source Temperatures, Deg. F-

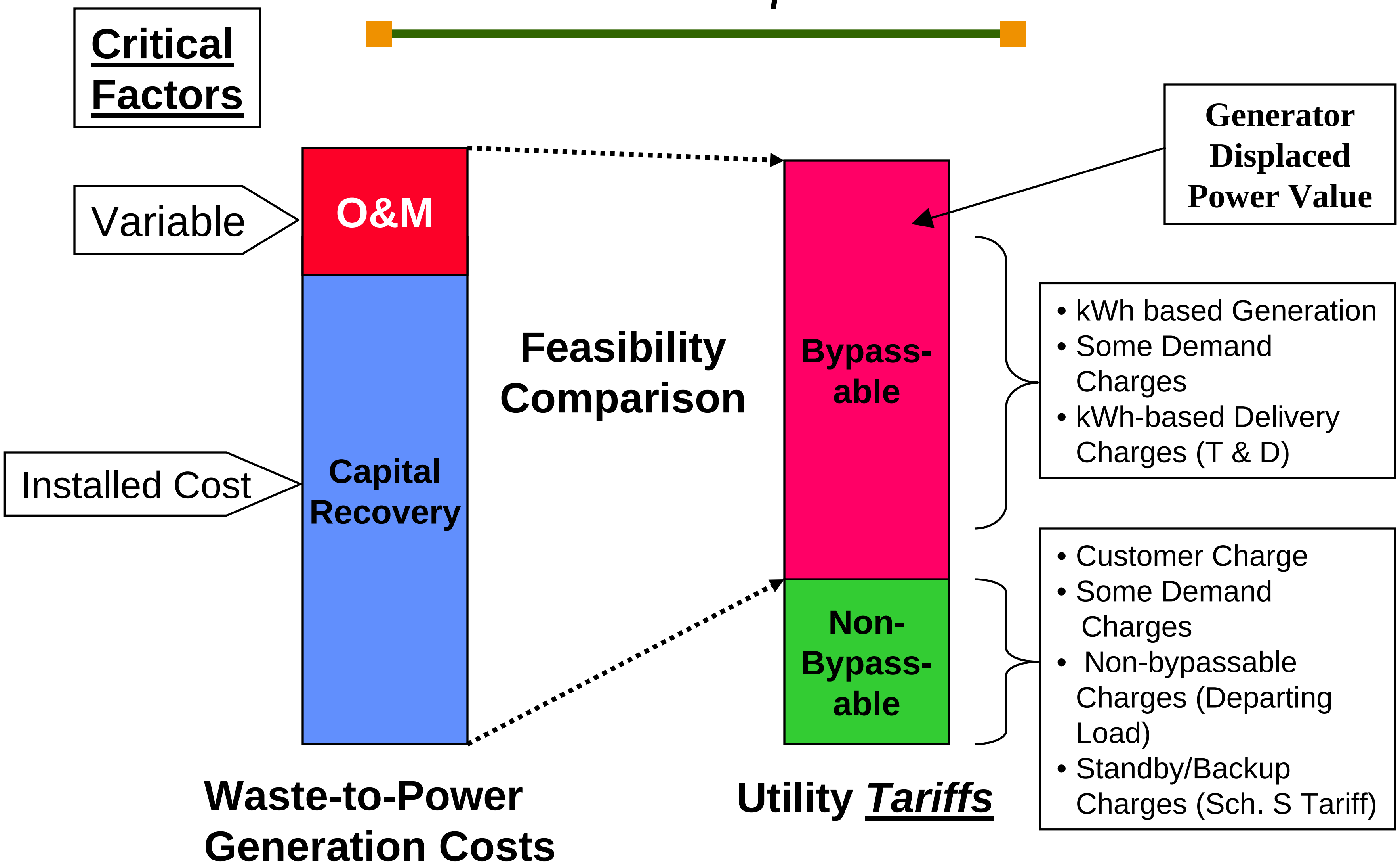
Waste Heat-To-Power Generation Project Economics

- Highly specific to physical configuration of customer operation
  - "Quality of heat" considerations:
    - Waste heat temperature and its variation
    - Mass flow variations (including downtimes, start-up & shut down times, etc.
    - Seasonality of waste heat availability (i.e. facilities that operate only during certain periods)
    - Availability of reliable power generation technology for low temperature (< 400 Degrees Fahrenheit)
    - Capital cost (power block & customer facility modification to facilitate waste heat source to power block), O&M cost
    - Investment return horizon and expected investment hurdle rate

Waste Heat-To-Power Generation Project Economics Misunderstood Factors - Customer Perspective

- SCE's Tariff based average cost of power is not the same as generator displaced power value.
- The "Value of the displaced power" is basically the difference between the average cost of power (with out generator) and the average cost of power for residual purchases (with generator) including standby charge, and departing load charges.
- Generator displaced power value is a function of:
  - Generator operating reliability (duration and time of occurrence of generator outages): SCE's Time-Of-Use tariff has energy and demand components by winter and summer season
  - Reduction in demand charge (or savings) could vary by month – each month is an independent event related to generator operating reliability
  - One 15 minute shutdown can result in loss of time-related demand benefit for the summer month

Waste Heat-to-Power Generation Customer Perspective



Proposal Economics

- In general most proposals are based on the simple payback method. This approach is far too simple to be relevant. It neglects the value of money.
  - After all, money is not free
- Another approach would be to calculate the cost to generate and compare it to the "value of the generator displaced power" expressed in $/kWh
- The method that provides the best financial basis for decisions is the life cycle cost analysis consisting of present worth and Internal Rate of Return (IRR).
  - If the IRR exceeds the customer's minimum acceptable rate of return for investment, then the project is economic.

Example: A foundry customer in SCE Service Territory

- Assume a 300 kW organic rankine cycle generator project (waste heat-to-power) connected to a TOU-8 service
- Installed cost: $600,000 ($2,000/kW)
- Generator reliability: 85% (7,500 hrs/yr) Two outages in summer on-peak period
- Fuel cost: zero (waste heat)
- O&M cost
- $0.02/kWh (includes routine maintenance, call-out work, and sinking fund for rebuilds)
- Investment hurdle rate: 15% before tax (Note: the value of money is not the cost to borrow)
- Project economic life: 10 years
- Capital recovery factor (CRF) = 0.2 or 20%
- Capital recovery @ 15% = $2,000/kW x0.2/7,500 hrs = $400kW/7,500 hrs = $0.0533/kWh
- Capital recovery @ 20% hurdle rate: $0.0640/kWh (appropriate for risky project)
- Cost to generate @ 15% hurdle rate: $0.0533 + $0.02 = $0.0733/kWh
- Cost to generate @ 20% hurdle rate: $0.0640 + $0.02 = $0.084/kWh
- Customer TOU-8 Tariff a average power cost: $0.1126/kWh
- Generator displaced power value: $0.0761/kWh
- Generator displaced power value > cost to generate (economic-move to next level of analysis)
- Generator displaced power value < cost to generate – not economic

Waste Heat-To-Power Generation – Electric Utility Perspective – Interconnection To Utility Grid

- California deregulation legislation created CAISO and energy market apparatus:
  - CPUC suspended utility contracts for Qualified Facilities (QFs) over 100 kW
  - Merchant Power Producers sell to wholesale customer and schedule deliveries through CAISO
  - Renewable Producers sell to utilities under Renewable Portfolio Standards (SB 1070)
  - Distributed Generation (DG) – may be any technology (including Waste Heat-To-Power) – QF or not
  - DG eligible for interconnection and standby service
  - DG typically serves onsite load, interconnects through CPUC rules (Rule 21)

Waste Heat-To-Power Generation – Electric Utility Perspective – Interconnection To Utility Grid

- **<u>SCE's Rule 21</u>**
  - Sets forth technical and procedural requirements for interconnection
  - Requires customer generation equipment to comply with all local, state and national codes
  - SCE's interconnection requirements are regulated by the California Public Utilities Commission
  - Rule 21 at other California IOUs are virtually identical to SCE's
  - Rule 21 is Technology and Size <u>NEUTRAL</u>

Waste Heat-To-Power Generation – Electric Utility Perspective
Interconnection To Utility Grid

- Arrangements and Agreements
  - Isolated Operation
  - Momentary Parallel Operation
  - Parallel Operation
    - Non-Exporting
    - Inadvertent Exporting
    - Net Energy Metering
    - Power Sales ‘to’ or ‘through’ SCE’s system

Waste Heat-To-Power Generation – Electric Utility Perspective

Renewable Portfolio Standard RFP Evaluation

- SB 1078 – September 2002
  - Established California RPS Program
  - 20% renewables by 2017
  - New procurement of 1% per year until goal is reached
  - Winners determined using a competitive bid process (Least-Cost/Best-Fit)
  - Renewable costs above a market referent price (MPR) are paid for by Public Goods Charge (PGC) funds, if available
- California Energy Action Plan - 2003
  - Three agencies – CPUC, CEC, CPA
  - Policy accelerates 20% goal to 2010
- Efforts to further increase goal to 33%

Waste Heat-to-Power Generation
Electric Utility Perspective

Renewable Portfolio Standard RFP Evaluation - Least-Cost/Best-Fit Evaluation Methodology

- Competitive Bid process to award contracts to projects
- Bids will be evaluated on a total cost basis and on a consistent set of economic assumptions.
- The bidding evaluation process is iterative,
  - 1st Iteration -- the total all-in price of like products compared,
  - 2nd Iteration -- re-ordered based on system fit (based on system simulation model analysis), plus integration and transmission costs.
- Least Cost and Best Fit resources selected for short list
- Short-list projects commence negotiations and conclude with contract execution (for those who are able to agree on terms)

Waste Heat-to-Power Generation
Electric Utility Perspective
Renewable Portfolio Standard RFP Evaluation – Market Price Referent Methodology

- Proxy plant methodology:
  - Uses a combined cycle proxy plant to determine the base-load product price equivalent
  - Uses combustion turbine proxy plant to determine the peaking product price equivalent
- CPUC will consider using actual contracts for calculating the market price referent if such contracts are available and appropriate.
- The market price referent will be compared to the actual bid prices.
  - IOUs required to pay the lesser of bid price or MPR values to the winning bidders
  - If bid price is greater than MPR, the amount in excess of the MPR will be paid by the Energy Commission from PGC Funds

Who to Contact at SCE

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- Generator Interconnection to SCE: Gerry Torribio, 626-302-9669 or Gerry.Torribio@sce.com
- Power Purchase Agreements – Renewable Portfolio Standards:
  http://www.sce.com/AboutSCE/Regulatory/qualifyingfacilities/RPS2005.htm