The Basics of Cost-Effectiveness Analysis

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Cost-effectiveness analysis of Demand Side Programs
What are demand-side programs?

- Energy Efficiency
- Low Income Energy Efficiency (Energy Savings Assistance Program, or ESAP)
- Demand Response
- Distributed Generation
Cost Benefit Analysis

Costs
- Administration
- Equipment
- Incentives
- Revenue Loss
- Value of Service Lost

Benefits
- Avoided Costs
- Environmental
- Incentives
- Bill Reductions
- Tax Credits

- Benefit Cost Ratio
- Net Benefits
- Payback Period
## Cost-Effectiveness Analysis

<table>
<thead>
<tr>
<th>Program</th>
<th>Benefit Cost Ratio</th>
<th>Net Benefits</th>
<th>Payback Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program A</td>
<td>3.28</td>
<td>$.123 M</td>
<td>11 years</td>
</tr>
<tr>
<td>Program B</td>
<td>1.05</td>
<td>$35.5 M</td>
<td>1 year</td>
</tr>
<tr>
<td>Program C</td>
<td>0.82</td>
<td>($9.036 M)</td>
<td>--</td>
</tr>
<tr>
<td>Program D</td>
<td>0.33</td>
<td>($15,678)</td>
<td>2 months</td>
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## Example of Discounted Cash Flow

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>TOTAL</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Benefits</strong></td>
<td></td>
<td></td>
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<tr>
<td>bill savings</td>
<td>$100</td>
<td>$100</td>
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<tr>
<td>rebate</td>
<td>$75</td>
<td>$0</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>$175</td>
<td>$100</td>
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<td><strong>Costs</strong></td>
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<tr>
<td>purchase price</td>
<td>$500</td>
<td>$0</td>
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<tr>
<td>installation</td>
<td>$150</td>
<td>$0</td>
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<tr>
<td>maintenance</td>
<td>$0</td>
<td>$0</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>$650</td>
<td>$0</td>
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<tr>
<td>annual benefits</td>
<td>($475)</td>
<td>$100</td>
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<tr>
<td>cumulative benefits</td>
<td>($475)</td>
<td>($375)</td>
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</table>

**Benefit Cost ratio**
- 1.13 at a discount rate of 4%
- 1.16 at a discount rate of 3%
- 1.1 at a discount rate of 5%

**Net Present Value**
- $99.53 at a discount rate of 4%
- $126.90 at a discount rate of 3%
- $74.42 at a discount rate of 5%

**Payback** approximately 7 years
How do discount rates and lifetimes affect cost-effectiveness?

| Benefits: | $100 per year energy savings + $75 rebate |
| Costs: | $650 initial investment + $50 maintenance every 2 years |

<table>
<thead>
<tr>
<th>10 year EUL</th>
<th>3%</th>
<th>5%</th>
<th>7%</th>
<th>9%</th>
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<tr>
<td>NPV benefits</td>
<td>$925.84</td>
<td>$843.60</td>
<td>$772.45</td>
<td>$710.57</td>
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<tr>
<td>NPV costs</td>
<td>$798.93</td>
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<td>$742.28</td>
<td>$717.81</td>
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<td>Net Present Value</td>
<td>$126.90</td>
<td>$74.42</td>
<td>$30.18</td>
<td>$(7.24)</td>
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<td>Benefit/Cost</td>
<td>1.16</td>
<td>1.10</td>
<td>1.04</td>
<td>0.99</td>
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</table>

<table>
<thead>
<tr>
<th>15 year EUL</th>
<th>3%</th>
<th>5%</th>
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<th>9%</th>
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<tr>
<td>NPV benefits</td>
<td>$1,266.61</td>
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<td>NPV costs</td>
<td>$865.07</td>
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<td>Net Present Value</td>
<td>$401.54</td>
<td>$289.65</td>
<td>$199.74</td>
<td>$127.03</td>
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<tr>
<td>Benefit/Cost</td>
<td>1.46</td>
<td>1.35</td>
<td>1.26</td>
<td>1.17</td>
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</table>

<table>
<thead>
<tr>
<th>20 year EUL</th>
<th>3%</th>
<th>5%</th>
<th>7%</th>
<th>9%</th>
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</thead>
<tbody>
<tr>
<td>NPV benefits</td>
<td>$1,560.56</td>
<td>$1,317.65</td>
<td>$1,129.49</td>
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<td>NPV costs</td>
<td>$923.84</td>
<td>$861.35</td>
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<tr>
<td>Net Present Value</td>
<td>$636.73</td>
<td>$456.30</td>
<td>$318.70</td>
<td>$212.54</td>
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<tr>
<td>Benefit/Cost</td>
<td>1.69</td>
<td>1.53</td>
<td>1.39</td>
<td>1.28</td>
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</table>
Discount Rates

Before-tax WACC, after-tax WACC, consumer, or social discount rate?

NRDC: Use a social discount rate for the TRC

- A social discount reflects the high value of investing in efficiency today to avoid energy use later and the need to meet our aggressive climate goals and the ever increasing costs of providing energy to customers. It’s consistent w/ how CEC values energy savings due to EE codes and standards.

TURN: The social discount rate is NOT appropriate

- Discount rates should reflect the real cost of raising capital to build the generation that is being avoided. This is the opportunity cost for projects that are not undertaken due to efficiency and what ratepayers would have to pay for them.
- If we are making tradeoffs of one type of investment versus another it is important that the same discount rate be used in these tradeoffs to properly allocate limited resources.

DRA, Efficiency Council: A consumer discount rate may sometimes be appropriate

- A consumer discount rate would, in theory, better reflect customers’ costs of borrowing money, or how customers value their investments.
- It is difficult to determine which consumer discount rates to use, for which groups of consumers, and under what circumstances
- Proposals range from mortgage rates to credit card rates.
Program Lifetime

- For EE and DG, the expected useful lifetime (EUL) of the equipment is used.

- For DR, the three year program cycle is used, with capital costs amortized over their lifetime.
The Standard Practice Manual (SPM)

• Developed to measure the cost-effectiveness of Energy Efficiency programs

• Use four tests to measure cost-effectiveness from four perspectives:
  – “Society”: The Total Resource Cost (TRC) test
    “Society” is actually Utility + Participant
  – Program Administrator: The Program Administrator (PAC) test
  – Ratepayers: The Ratepayer Impact Measure (RIM) test
  – Participant: The Participant Test

• The SPM also describes the “Societal Cost Test,” a variant of the TRC that includes externalities and uses a social discount rate. This has been proposed by ED staff but not adopted by the CPUC.
Problems with the SPM tests

- Critics claim that TRC includes all participant costs but not all participant benefits (we disagree, but participant costs, especially for DR, are very hard to quantify).
- Avoided costs difficult to define and measure precisely, inputs always contentious.
- Other cost and benefit inputs have contentious or difficult aspects.
- Externalities such as environmental impacts usually excluded; hard to quantify when included.
- Unclear how to use each test for decision-making, decision-makers don’t like imprecision.
- Most inputs involve measuring things that didn’t happen.
## Cost and Benefits Used

<table>
<thead>
<tr>
<th>Measure</th>
<th>EE/DG TRC</th>
<th>EE/DG PAC</th>
<th>DR TRC</th>
<th>DR PAC</th>
<th>RIM</th>
<th>DR Participant</th>
<th>ESAP TRC</th>
<th>ESAP MPT (participant)</th>
<th>ESAP UCT</th>
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<tr>
<td>Administrative costs</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
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<tr>
<td>Avoided costs of supplying electricity</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
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<tr>
<td>Bill Increases</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>COST</td>
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<tr>
<td>Bill Reductions</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>BENEFIT</td>
</tr>
<tr>
<td>CAISO Market Revenue</td>
<td></td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td></td>
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<tr>
<td>Capital costs to participant</td>
<td>COST</td>
<td>COST</td>
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<td>COST</td>
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<tr>
<td>Capital costs to utility</td>
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<td>COST</td>
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<tr>
<td>Environmental benefits (GHG only)</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
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<tr>
<td>Incentives paid</td>
<td></td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
<td>COST</td>
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<tr>
<td>Increased supply costs</td>
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<td>COST</td>
<td>COST</td>
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<td>COST</td>
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<td>Market benefits</td>
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<td>BENEFIT</td>
<td>BENEFIT</td>
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<td>BENEFIT</td>
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<tr>
<td>Non-monetary/Non-energy benefits</td>
<td></td>
<td></td>
<td>BENEFIT</td>
<td></td>
<td>BENEFIT</td>
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<tr>
<td>Revenue gain from increased sales</td>
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<td>BENEFIT</td>
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<tr>
<td>Revenue loss from reduced sales</td>
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<td></td>
<td></td>
<td></td>
<td>COST</td>
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<td></td>
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<tr>
<td>Tax Credits</td>
<td>BENEFIT</td>
<td>BENEFIT</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Value of service lost and transaction costs to participant</td>
<td></td>
<td></td>
<td>COST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>COST</td>
</tr>
</tbody>
</table>

*Blue* text indicates optional, hard-to-quantify benefits. (DR only)

*Italic* text indicates that value may be different for different tests.

*Green* text indicates values that are often considered to be externalities.
Significant Costs and Benefits

COSTS

• Administration
  (e.g., program design, development, operations, maintenance, overhead, customer service, marketing & outreach, sales, IT infrastructure, customer education, program evaluation, measurement & verification)

• Measure (Capital) Costs
  (equipment costs incurred by the utility and participants)

• Incentives

• Revenue Loss
  (bill reductions)

• Participant Costs
  (Other than capital costs – value of service lost & transaction costs)

BENEFITS

• Avoided Costs
  (complex)

• Tax Credits
  (currently available for DG only)

• Market/Reliability Benefits

• Non-energy benefits

• Incentives

• Bill reductions
Energy Efficiency Impact on Load

Original Load (hottest day of the year)

Reduced Load due to Energy Efficiency

Avoided Capacity

Avoided Energy
Demand Response Impact on Load

- **Original Load (hottest day of the year)**
- **Reduced Load Due to Demand Response**

**Avoided Capacity**

Avoided Energy only during events
Distributed Generation Impact on Load

- **Original Load (hottest day of the year)**
- **Reduced Load Due to Distributed Generation**

- **Avoided Capacity**
- **Avoided**
Avoided Cost Calculator

Calculates 6 types of avoided costs:

• (Generation) Capacity
• Energy
• Transmission & Distribution Capacity (T&D)
• Ancillary Services
• Renewable Portfolio Standard
• Greenhouse Gas (GHG)
Avoided Cost of Capacity

• Short term avoided capacity costs:
  – short term value of capacity is based on current resource adequacy values, whose low magnitudes ($28/kW-yr in 2008) reflect the CAISO’s large current capacity surplus. This value is linearly extrapolated from 2008 to the RBY.

• Long term avoided capacity costs:
  – Determine cost of building a new Combustion Turbine (CT), including environmental compliance
  – Subtract gross margins (revenues from energy and ancillary service sales) to determine Residual Capacity Value (annual value in $/kW-year)
The RBY is the point in the future when existing capacity (in the absence of demand side resources or new generation) will be unable to meet demand. In this example, the RBY is 2015.

Before RBY: short term value of capacity is based on current resource adequacy values

After RBY: long term value of capacity is based on construction of a new Combustion Turbine (CT)
Allocating the Residual Capacity Value

Annual Avoided Costs are spread over each month or hour of the year, based on when supply is likely to be insufficient to meet demand.

Which Loss of Load Expectation (Loss of Load Probability) Model should we use?

- IOU models (more precise and accurate according to utilities, but are proprietary, opaque, use confidential data, and are run infrequently).
- E3 default (simple) model spreads the value over the top 250 hours.
- Some prefer same model which spreads the value over the 100 hours.
- Utilities suggested a mathematical function which mimics their LOLE output.
- E3 suggested a new, somewhat more complex version of their default model.
- Same model is used to determine A factor so the LOLE model used is a key component of DR cost-effectiveness.
- SERVm: run by ED staff, includes DR, but not ready yet.
Avoided Cost of EE

+ **Capacity**: Residual Capacity Value x Loss of Load Expectation for each hour

+ **Energy**: Hourly energy prices, based on historical data and forecast prices.

+ **T&D**: IOU-specific costs x hourly allocators based on historical weather data. Different for each climate zone.

+ **Ancillary Services**: % of energy

+ **GHG**: GHG price

+ **RPS**: Renewable Premium (difference between the average cost of a CCGT and the cost of a particular group of RPS projects)

= \$/kWh
Determining Avoided Costs of an EE Measure

Annual avoided costs are calculated for each hour of the year, based on the sum of the six avoided costs.

Hourly Avoided Costs are multiplied by the hourly load savings for each measure...

... to determine the Avoided Cost benefit for that measure.
Calculating Avoided Costs for DR

- **Capacity**: Residual Capacity Value \( \times \) Loss of Load Expectation for each month \( \times \) monthly load impact \( \times A \) Factor \( \times B \) Factor \( \times C \) Factor

- **Energy**: Average energy price \( \times E \) factor \( \times \) total avoided energy (monthly call hours \( \times \) monthly load impact, for each month)

- **T&D**: IOU-specific annual data \( \times D \) Factor

- **Ancillary Services**: currently zero

- **GHG**: GHG price \( \times \) total avoided energy

- **RPS**: Renewable Premium (difference between the average cost of a CCGT and the cost of a particular group of RPS projects) \( \times \) total avoided energy
## DR Avoided Cost Adjustment Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Availability</td>
<td>Adjusts the capacity value that can be captured by the DR program based on the time of operation and the frequency and duration of calls permitted.</td>
</tr>
<tr>
<td>B</td>
<td>Notification Time</td>
<td>Accounts for differences in value of various notification times (e.g., day-ahead, day-of, 30 minute, 15 minute)</td>
</tr>
<tr>
<td>C</td>
<td>Trigger</td>
<td>Accounts for value of flexibility of the triggers or conditions that permit the utilities to call each DR program</td>
</tr>
<tr>
<td>D</td>
<td>Distribution</td>
<td>Adjusts estimated benefits based on avoided transmission and distribution (T&amp;D) costs related to “right time,” “right place,” “right certainty,” and “right availability” of DR programs</td>
</tr>
<tr>
<td>E</td>
<td>Energy Price</td>
<td>Adjusts estimated benefits based on avoided energy costs attributable to DR programs</td>
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</tbody>
</table>
EE Measure Costs

- Incremental Measure Cost = Difference between baseline and efficient model
- Free-ridership = Costs that would have been incurred even if program did not exist
- Net-to-Gross ratio = Free-ridership/Total participants
- Both benefits (energy savings) and costs (participant share of measure costs) reduced using the NTG ratio, so that only costs and benefits caused by the EE measure are included in the calculation, although the cost of rebates paid to free-riders is also included.
EE Measure Costs (cont.)

See “Ex Ante Review Fact Sheet #1

• Replace on Burnout
  – Incremental energy savings based on new equipment, not existing.

• Early Retirement
  – Remaining life is estimated and adjustments made.

• Codes and Standards/Industry Standard Practice
  – Saving estimates usually calculated as the “above code” portion of the savings.
  – Exception made if data indicates standard practice is far below code.
Incentives

• TRC costs include both utility and participant costs.
• Utility costs = Admin costs + incentive costs
• Participant costs = Equipment costs – incentive costs (+ other costs for DR)
• Incentive costs cancel out when you add them together.
• Accounting is complicated because incentives can be upstream, midstream or downstream.
Participant Costs

• Energy Efficiency:
  • Net (after rebate) Incremental Measure Costs x Net-to-Gross Ratio

• Demand Response (DR):
  • Event-based DR: Value of Service Loss + Transaction Costs
    *(75% of incentives used as proxy)* + Capital Costs (often zero)
  • Permanent Load Shifting: Total Cost of Installed System – Rebate

• Distributed Generation (DG):
  • Total Cost of Installed System – Federal Tax Credits – Rebate
Non-Energy Benefits

- **Participant NEBs** accrue to the program participants (such as reduced building operating costs, increased value, comfort, health, and safety).
- **Utility NEBs** are realized as indirect costs or savings to the utility (such as bill payment improvements, infrastructure savings, etc.).
- **Societal NEBs** represent indirect program effects beyond those realized by ratepayers/utility, and they accrue to society at large (such as job creation, tax receipts growth, labor productivity, housing value, neighborhood stability, and reduced emissions and health care costs and other environmental benefits).
- There also may be non-energy costs, although many of these are included in value of service lost and transaction costs.
ESAP (low income EE) tests

- **MPT – Modified Participant Test**
  - Benefits are bill reductions and participant non-energy benefits
  - Costs are measure costs (administrative and capital costs of the measure)

- **UCT – Utility Cost Test**
  - Benefits are the avoided costs of the energy savings and utility non-energy benefits (NEBs)
  - Costs are measure costs (administrative and capital costs of the measure)

- **TRC – Total Resource Cost**
  - Benefits are the avoided costs of the energy savings
  - Costs are measure costs (administrative and capital costs of the measure)

Avoided costs and NEBs are calculated by discounting annual values over the lifetime of the equipment to determine the Net Present Value.

The % of ESAP’s administrative costs and NEBs assigned to each measure are based on the measure’s energy savings.
Cheat Sheet of Cost-effectiveness Concepts

Standard Practice Manual  TRC, PAC, RIM, PCT, MPT, UCT
Discount Rate  WACC, social discount rate, consumer discount rate
Effective Useful Lifetime (EUL)
Administrative Costs
Measure Costs  incremental measure costs, net-to-gross, free-ridership
Incentives  rebates, upstream, midstream, downstream
Revenue Loss  bill reductions
Participant Costs  value of service lost & transaction costs
Avoided Costs  capacity, energy, T&D, ancillary services, RPS, GHG
Resource Balance Year, Residual Capacity Value, LOLE/P; Adjustment Factors, Load Impacts, Energy Savings
Non-energy benefits  participant, utility, social