REPORT FROM

OFFICE OF PUBLIC ACCOUNTABILITY

Date: April 12, 2019

To: The Board of Water & Power Commissioners
   David Wright, General Manager, Department of Water & Power
   Nancy Sutley, Assistant GM of Water & Power, Sustainability

From: Frederick H. Pickel, Ph.D., Executive Director/Ratepayer Advocate

Reference: Preliminary OPA review of the DWP Worley Parsons / Navigant draft study on Once-Through Cooling alternatives

RECOMMENDATIONS

1. The Office of Public Accountability/Ratepayer Advocate (OPA) recommends that the Department of Water & Power (DWP) avoid irrevocable actions or inaction that reduce the alternatives for replacing or eliminating the remaining Once-Through Cooling (OTC) power generation at the Scattergood, Harbor, and Haynes generation plant sites (the OTC plants). This would include, for example, selling, leasing, assigning, mortgaging, securitizing or otherwise disposing of or encumbering real estate, emissions allowances, or other key assets, resources, or permits.

2. OPA recommends continued study of the near-term (under 5 years) and intermediate-term (up to 2030) alternatives for the OTC plants. This should include consideration of more agile fossil generation mixed with dispatchable renewable resources before, during, or after the OTC plants cease to use ocean cooling.

DISCUSSION

1. OPA, extensively assisted by the Brattle Group, monitored DWP’s independent consulting team led by Worley Parsons and Navigant during their year-long study of the OTC alternatives. The OPA’s Brattle representative was embedded with the consulting team. Brattle’s preliminary analysis of the draft DWP OTC study is attached.

2. The Brattle analysis suggests that the best mix of resources to replace OTC units is sensitive to assumptions that include carbon prices, fuel prices, discount rates, and the
unit costs of generation. The best cost and carbon reduction opportunities change when these sensitivities are evaluated. Technology maturity along with its related unit cost and timing effects constitute large risks to DWP ratepayers.

3. The draft OTC study, presented to the Board in November of 2018, did not include consideration of more agile generators like peaking units or reciprocating engines in or near these OTC sites.

4. The Brattle analysis suggests that mixing some faster ramping fossil generation at these sites may be economically attractive as a hedge on timing long term investments, even if unit costs are very high.

5. OPA believes this additional analysis may:

   1) reveal opportunities for DWP to improve the reliability of DWP service and voltage support near load pockets like the airport and the harbor,

   2) balance the cost, carbon reduction, innovation and investment timing of rapidly evolving non-fossil and storage resources, and thus

   3) allow DWP to safely select a more aggressive reduction of carbon sooner than would otherwise be feasible.

Additional operational analysis to explore the reliability of faster ramping fossil options should be included in future studies like DWP’s Strategic Long-Term Resource Plan and its 100% renewable study with the National Renewable Energy Lab.

cc: The City Council Committee on Energy, Climate Change & Environmental Justice
The Honorable Eric Garcetti, Mayor
Sharon Tso, Chief Legislative Analyst
Richard H. Llewellyn, City Administrative Officer
LADWP OTC Study
Carbon Emission Analysis
Preliminary - FOR DISCUSSION PURPOSES

PREPARED FOR
RPA/OPA

PREPARED BY
Bruce Tsuchida
Lynn Zhang

February 20, 2019
Revised March 1, 2019

Preliminary: These results will not be final until LADWP finalizes its OTC Report.
Executive Summary

- OTC Study was reviewed from a GHG emissions perspective.
  - Can the OTC Study show a viable path for achieving the LA 100% goal?
- High–level analyses performed
  - Which of the 12 Final Alternative Cases (hereafter referred to as “Cases”) are in line with the SB 100 goal and timeline?
  - How sensitive are the OTC Study results to various assumptions?
  - What is the per-unit cost of carbon reduction?
  - Are there alternatives to the repowering of existing Scattergood units?
- Preliminary conclusions (warranting further analyses)
  - Study results (NPV calculations) are sensitive to assumptions.
  - When compared to each other, NPVs by Case could fall within the noise range of ±5%.
  - Given the uncertainty of the assumptions for the non-emitting resources, which are rapidly developing, investment timing may be one of the most critical considerations.
  - Small-scale investments for bridging purposes may help retain reliability while identifying the ideal investment type and timing.
Agenda

- Review of OTC Study Results
  - Study Overview and Assumptions
  - Study Results Summary (Modified Results)
  - Range of Assumptions and Uncertainty
- OTC Study Cases and SB 100
  - Which of the 12 Alternative Cases are in line with the SB 100 goal and timeline?
- OTC Study Results Observations
  - Total Costs and Carbon Emissions: How the 12 Alternative Cases compare to the Baseline Case.
    - Discount Rate Sensitivities
    - Higher and Lower Range Cost Assumptions Sensitivities
    - Combined Assumptions Sensitivities
  - Per Unit of Carbon Reduction Cost
  - Scattergood Repowering Alternatives (Delayed OTC compliance)
- Appendix
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Study Scope and Period
- Study scope is to evaluate alternatives to LADWP’s 2016 IRP OTC repowering plan.
  - Study compares alternative options to repowering OTC units using non-emitting resources.
- Study period is over 22 years (2021 through 2042).
  - Study performs ProMod simulation for three years (2022, 2027, and 2036).
    - 2027: After Scattergood repowering (2025 – 2029) before Haynes/Harbor repowering.
  Market conditions are assumed to be at equilibrium after 2036 (operational reliability through production has not been confirmed for 2037 and after).

Study Results
- 12 Final Alternative Cases were evaluated and compared against the Baseline Case (with all OTC Units repowered)
  - Net Present Value (NPV) calculations assume 5.3% discount rate.
  - All NPV calculations are performed for a Higher and Lower Range Cost assumptions.
  - Most comparisons in this document (and the OTC Study presentation) use the Higher Range Cost assumptions for comparison.
Study Approach for evaluating non-emitting alternatives to LADWP’s 2016 IRP OTC repowering plan.

- **Resource Adequacy**
  - Are there enough generation to keep lights on?
- **Technical Feasibility**
  - Adequate resources and space for development?
- **Transmission Reliability**
  - Can transmission handle it?
- **System Simulation**
  - What are the production costs and GHG emissions?
- **Operability Analysis**
  - Can the system be reliably operated under contingencies?
- **Implementation**
  - Can the projects be built in time?
- **Metrics Score**
  - Ranking of successful project portfolios (Cases)

**Source:** OTC Study Update presentation
# Review of OTC Study Results

## Final 12 Cases Summary

<table>
<thead>
<tr>
<th>Cases</th>
<th>Repowered Projects</th>
<th>Mitigation Alternatives</th>
<th>NPV Costs ($ billions)*1</th>
<th>GHG Emissions*2</th>
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<td>Energy Storage (ES)</td>
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<td>Scattergood, Harbor &amp; Haynes (x1)</td>
<td>Solar, ES, EE, DR</td>
<td>16.58</td>
<td>5.60</td>
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<td>5.10</td>
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*1: The OTC Study group has revised NPV calculations for several cases and therefore may not match those from the earlier presentations. See Appendix for details.

*2: GHG emissions reported here are the expected annual averages from 2022, 2027, and 2036 ProMod simulations.
Review of OTC Study Results

Study Results (12 Cases) Ranking

Evaluation Metrics
- 12 sensitivities of category weights tested

Rankings

<table>
<thead>
<tr>
<th>Rank</th>
<th>Technical Scoring</th>
<th>Eliminated Gas Repowering</th>
<th>Technical + Cost Scoring</th>
<th>Eliminated Gas Repowering</th>
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<tr>
<td>1</td>
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<td>Eliminate 630 MW at Haynes</td>
<td>I</td>
<td>Eliminate 245 MW at Harbor</td>
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<tr>
<td>2</td>
<td>V</td>
<td>Eliminate 630 MW at Haynes</td>
<td>III</td>
<td>Eliminate 460 MW at Haynes</td>
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<td>3</td>
<td>I</td>
<td>Eliminate 245 MW at Harbor</td>
<td>VI</td>
<td>Eliminate 630 MW at Haynes</td>
</tr>
<tr>
<td>4</td>
<td>III</td>
<td>Eliminate 460 MW at Haynes</td>
<td>V</td>
<td>Eliminate 630 MW at Haynes</td>
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<tr>
<td>5</td>
<td>X</td>
<td>Eliminate 1,090 MW at Haynes and 326 MW at Scattergood</td>
<td>II</td>
<td>Eliminate 326 MW at Scattergood</td>
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<td>IX</td>
<td>Eliminate 1,090 MW at Haynes and 245 MW at Harbor</td>
<td>IX</td>
<td>Eliminate 1,090 MW at Haynes and 245 MW at Harbor</td>
</tr>
<tr>
<td>7</td>
<td>VIII</td>
<td>Eliminate 1,090 MW at Haynes</td>
<td>X</td>
<td>Eliminate 1,090 MW at Haynes and 326 MW at Scattergood</td>
</tr>
<tr>
<td>8</td>
<td>II</td>
<td>Eliminate 326 MW at Scattergood</td>
<td>VIII</td>
<td>Eliminate 1,090 MW at Haynes</td>
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<tr>
<td>9</td>
<td>VII</td>
<td>Eliminate 1,090 MW at Haynes</td>
<td>VII</td>
<td>Eliminate 1,090 MW at Haynes</td>
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<td>10</td>
<td>XI</td>
<td>Eliminate all 1,661 MW</td>
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<td>Eliminate 326 MW at Scattergood and 245 MW at Harbor</td>
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<td>11</td>
<td>IV</td>
<td>Eliminate 326 MW at Scattergood and 245 MW at Harbor</td>
<td>XI</td>
<td>Eliminate all 1,661 MW</td>
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<tr>
<td>12</td>
<td>XII</td>
<td>Eliminate all 1,661 MW</td>
<td>XII</td>
<td>Eliminate all 1,661 MW</td>
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</tbody>
</table>

Recommendation

- Eliminate 2 of the 3 re-powering projects at Haynes
- Repower Scattergood
- Repower Harbor

Source: OTC Study Update presentation
For each Case, the OTC Study calculates two GHG emission metrics:

- In-Basin only emissions
- In-Basin emissions adjusted for emissions from net imports

While Cases XI and XII (no OTC repowering) have the lowest In-Basin emissions, Case X has the lowest adjusted emissions.

**GHG Emissions by Case**

*Expected 2022 emissions level in OTC Study.*

Compare to historical emissions levels (from 2017 SLTRP*):

- 1990: 17.9 MMT
- 2016: 10.7 MMT

### High and Low Range Cost Assumptions by Resource and Cost Type

<table>
<thead>
<tr>
<th>Resource</th>
<th>Low Range</th>
<th>High Range</th>
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<tbody>
<tr>
<td><strong>OTC Repowering Capital Costs (2016 $/kW)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scattergood 8 &amp; 9</td>
<td>$1,350</td>
<td>$1,200</td>
</tr>
<tr>
<td>Haynes 17 &amp; 18</td>
<td>$1,450</td>
<td>$1,300</td>
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<tr>
<td>Haynes 19 &amp; 20</td>
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<tr>
<td>Haynes 21 &amp; 22</td>
<td>$1,450</td>
<td>$1,300</td>
</tr>
<tr>
<td>Harbor 15 &amp; 16</td>
<td>$1,650</td>
<td>$1,500</td>
</tr>
<tr>
<td><strong>Mitigation Alternative Capital Costs (2016 $/kW)</strong></td>
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<td></td>
</tr>
<tr>
<td>Storage (4-hour)</td>
<td>$1,500</td>
<td>$1,700</td>
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<tr>
<td>Rooftop Solar</td>
<td>$2,324</td>
<td>$2,961</td>
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<tr>
<td>Incremental EE</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Incremental DR</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Geothermal</td>
<td>$5,000</td>
<td>$6,000</td>
</tr>
<tr>
<td>Wind</td>
<td>$1,900</td>
<td>$2,100</td>
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<tr>
<td>Floating Solar</td>
<td>$1,600</td>
<td>$1,800</td>
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<tr>
<td>Land-Based Solar (In-basin)</td>
<td>$1,400</td>
<td>$1,600</td>
</tr>
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</table>

| Net Interchange Costs (2016 $/MWh)* | | |
| Range, Depending on Year and Scenario | $0 - $3 | $2 - $8 |

* Net Interchange Cost ranges are estimated based on ProMod outputs for scenarios V and XII.

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Uncertainty of cost assumptions indicates error range for total cost NPV to be **around 5% (≈$0.75 B, compared to Baseline of $15 B)**.
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- Appendix
Observation: All 12 Final Cases (each case is shown in the purple diamonds) are on track to achieve SB 100 by 2045.
Observations:

- If SB 100 is defined to only include RPS eligible resources, several cases (including the Base Case) may require a post-2036 boost to achieve SB 100 by 2045.
- Case VI and VII may (with very little margin) satisfy the 60% by 2030 target.
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OTC Study Results Observations

Total Costs and Carbon Emissions

- Compares the 12 Final Alternative Mitigation Case NPVs to the Baseline Case (with all OTC units repowered) NPV.
  - GHG emissions reflect total In-Basin emissions adjusted for net imports, over the 22 year study period.
    - Emission quantities are not discounted over the years.
  - All NPVs calculated for the 22 year study period (2021-2042) using cash flow data provided by OTC Study team.
    - Uncertainty of various assumptions indicates NPV difference of 5% or so to be within noise of analyses.
- Sensitivities analyzed for:
  - Discount Rate Sensitivities
  - Higher and Lower Range Cost Assumptions Sensitivities
  - Combined Assumptions Sensitivities
OTC Study Results Observations

Case Comparison – Cost and Emissions

Cost

GHG Emissions

Lower                           Higher

Lower                             Higher

GHG Emissions

2021-2042 Total GHG Emissions (MMT)

Total Cost NPV ($B)

Better

Worse

Baseline
OTC Study Results Observations

5.3% / 10% Discount Rate – All Years

Discount Rate (DR) Sensitivity

- Navy marks show NPVs for 5.3% DR Case (assumes 5.3% discount rate for everything).
  - Includes Baseline Case.
- Teal marks show NPVs for 5.3%/10% DR Case (assumes 5.3% discount rate for OTC repowering and LADWP operational costs, and 10% discount rate for other investments).

Current LADWP-wide emission is assumed to be around 181 MMT.
(based on 2022 ProMod simulation results)

- Impact of discount rate choice is much larger for higher number Cases (with less OTC repowering).
Higher Range vs. Lower Range Assumptions Sensitivity

- Navy marks show NPVs for Higher Range assumptions.
- Teal marks show NPVs for Lower Range assumptions.
  - Includes Baseline Case.
  - Both assume 5.3% DR Case.

Current LADWP-wide emission is assumed to be around 181 MMT. (based on 2022 ProMod simulation results)

- Impact of Higher Range vs Lower Range assumption is much larger for higher number Cases (with less OTC repowering)
OTC Study Results Observations

Combined Cost Sensitivities – All Years

Combined (Higher/Lower Range + Discount Rate) Sensitivity

- Navy marks show NPVs for 5.3% DR Case with Higher Range assumptions.
- Teal marks show NPVs for 5.3%/10% DR Case with Lower Range assumptions.
  - Includes Baseline Case.

Current LADWP-wide emission is assumed to be around 181 MMT.
(based on 2022 ProMod simulation results)

- Combined effect eliminates NPV difference among the various Cases, favoring higher number Cases (with less OTC repowering).
The NPVs of total costs (2017 $ billions) for each Case are shown in the table below for various levels of carbon price assumption.

- Cases are listed in order of lowest total cost to highest total cost.
- Teal highlighting indicates when the order of a Case remains consistent.

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<thead>
<tr>
<th></th>
<th>Base</th>
<th>2x</th>
<th>4x</th>
<th>6x</th>
<th>8x</th>
<th>10x</th>
<th>12x</th>
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<tr>
<td>Carbon Price Assumptions ($/metric ton emissions)</td>
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<td></td>
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<tr>
<td>2022</td>
<td>$18.66</td>
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<tr>
<td>Ranking of Cases by Total Cost NPV (2017 $B)</td>
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Values based on Brattle calculation using Higher Range Cost assumptions based cash flow data.
As carbon price assumptions increase, the **total cost NPVs** increase for all Cases, but at different rates.

### Base Carbon Price Assumption
*Used for OTC Study*

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<tr>
<th>Year</th>
<th>Base Carbon Price $/metric ton</th>
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</thead>
<tbody>
<tr>
<td>2022</td>
<td>$18.66</td>
</tr>
<tr>
<td>2027</td>
<td>$23.79</td>
</tr>
<tr>
<td>2036</td>
<td>$36.90</td>
</tr>
</tbody>
</table>

**Observations:**
- The **Baseline NPV** is the lowest cost option under Base carbon price assumptions, but becomes the highest cost option when carbon prices increase.
- Cases that involve less or no OTC repowering (**IX, X, XI, XII**) have comparatively low costs when carbon prices increase.
As carbon price assumptions increase, the **per unit carbon reduction costs** increase for all Cases, but at different rates.

### Observations:
- **Case X** consistently has the lowest per unit cost of carbon reduction cost.
- Cases that involve no OTC repowering (XI and XII) have comparatively low per unit carbon reduction costs when carbon prices increase.
Additional analyses for delaying the existing Scattergood units OTC compliance date by ten years (~2035).

- Operating Scattergood at 5% capacity factor (annual average) can yield lower overall NPV (calculated through 2045) than for Alternative Mitigation Cases that repowers Scattergood.
  - Most mitigation alternative costs (with the exception of rooftop solar, shown in red text in the table below) will yield lower NPVs.
  - No operational restrictions are considered.
- Potentially indicates replacing OTC units with smaller units (simple cycle GTs or RICE units) with lower investment costs to be a viable solution.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Assumed Annual Capacity Factor</th>
<th>Investment Costs ($/kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Range</td>
</tr>
<tr>
<td>Wind</td>
<td>30%</td>
<td>$1,900</td>
</tr>
<tr>
<td>Storage (4-hour)</td>
<td>75%</td>
<td>$1,500</td>
</tr>
<tr>
<td>Geothermal</td>
<td>90%</td>
<td>$5,000</td>
</tr>
<tr>
<td>Rooftop Solar</td>
<td>25%</td>
<td>$2,324</td>
</tr>
<tr>
<td>Land-Based Solar (In-basin)</td>
<td>25%</td>
<td>$1,400</td>
</tr>
<tr>
<td>Floating Solar</td>
<td>25%</td>
<td>$1,600</td>
</tr>
</tbody>
</table>
Scattergood Repowering Alternatives – 2/3

Scattergood @ 5% CF + Wind

Scattergood @ 5% CF + Geothermal
The addition of a new gas-fired unit in 2025 (to replace existing Scattergood running at 5% capacity factor) can also yield lower overall NPV.

**Assumptions for New Gas Unit**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>50 MW</td>
</tr>
<tr>
<td>Capacity Factor</td>
<td>30%</td>
</tr>
<tr>
<td>Investment Cost</td>
<td>$2000/kW</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>= Original Scattergood</td>
</tr>
</tbody>
</table>

*Note: If the new investment is a 20 MW unit with investment costs of $1,500/kW and operating costs of 80% Original Scattergood (reflecting higher fuel efficiency), then the grey bar would become about equal to the teal bar.*
Agenda

- Review of OTC Study Results
  - Study Overview and Assumptions
  - Study Results Summary (Modified Results)
  - Range of Assumptions and Uncertainty

- OTC Study Cases and SB 100
  - Which of the 12 Alternative Cases are in line with the SB 100 goal and timeline?

- OTC Study Results Observations
  - Total Costs and Carbon Emissions: How the 12 Alternative Cases compare to the Baseline Case
    - Discount Rate Sensitivities
    - Higher and Lower Range Cost Assumptions Sensitivities
    - Combined Assumptions Sensitivities
  - Per Unit of Carbon Reduction Cost
  - Scattergood Repowering Alternatives (Delayed OTC compliance)

- Appendix
Appendix

- Review of OTC Study Results
  - Updates to NPV Calculations
  - Study Results GHG Emissions
  - Uncertainty Ranges and Cost Sensitivities

- OTC Study Results Observations
  - Discount Rate Sensitivities
    - 10% Discount Rate – All Years
    - 5.3% / 10% Discount Rate – 2036 Only
  - Carbon Cost Analysis Sensitivity
  - Carbon Reduction Cost Analysis
  - Scattergood Repowering Alternatives
Appendix: Review of OTC Study Results

Updates to NPV Calculations

- Presentation shows Baseline Case NPV of $15 billion, and not the 2016 IRP.
- All Alternative Case NPVs are compared to the Baseline NPV.
  - OTC Study NPVs are calculated over 22 years.

- Cases highlighted in yellow above were updated.
  - NPV delta is against the Baseline Case NPV of $15.0 B.
  - Baseline Case has a range of $14.6 B - $15.4 B, which average to $15.0 B.
Appendix: Review of OTC Study Results

Study Results GHG Emissions

Source: OTC Study Update presentation
Appendix: Review of OTC Study Results

Uncertainty Ranges

- OTC Study results have uncertainty ranges.

**Sensitivity Cost Ranges**

<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Case A</th>
<th>Case B</th>
<th>Absolute (2017 $B) % of Case A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OTC Study Baseline</strong></td>
<td><strong>High: $15.38</strong></td>
<td>Low: $14.65</td>
<td>$0.74 4.8%</td>
</tr>
<tr>
<td><strong>Brattle Calculation from OTC Cash Flow Data</strong></td>
<td><strong>High: $15.33</strong></td>
<td>Low: $14.53</td>
<td>$0.80 5.2%</td>
</tr>
<tr>
<td>Higher gas price (20%) sensitivity</td>
<td>Higher Gas Price: $17.04</td>
<td>$1.71 11.2%</td>
<td></td>
</tr>
<tr>
<td>Higher emission price (20%) sensitivity</td>
<td>Higher Emission Price: $15.85</td>
<td>$0.52 3.4%</td>
<td></td>
</tr>
</tbody>
</table>

- The general range of error appears to be *around 5% (≈$0.75 B).*
  - Fuel price sensitivity is larger compared to other input assumptions.
  - Emission costs and Renewable Capital costs follow.
Appendix: Review of OTC Study Results

Cost Sensitivities – 20% Increase

* Note: Scenarios with purple labels involve Scattergood repowering.
Appendix: Review of OTC Study Results

Cost Sensitivities – 20% Reduction

* Note: Scenarios with purple labels involve Scattergood repowering.
Appendix: OTC Study Results Observations

10% Discount Rate – All Years

10% Discount Rate Sensitivity

Lower Cost Range + 10% Discount Rate Sensitivity

* Note: Scenarios with purple labels involve Scattergood repowering.

- Navy marks show NPVs for 5.3% DR Case with Higher Range assumptions.
- Teal marks show NPVs for 10% DR Case (assumes 10% discount rate for all investment and operating costs).
  - Chart on the left applies 10% DR to higher range cost assumptions; chart on the right applies 10% DR to lower range cost assumptions.
- Includes Baseline Case.

GHG emission quantity not discounted.
Appendix: OTC Study Results Observations

5.3% / 10% DR – 2036 Only

2036 Cost and Emissions by scenario for the 5.3% / 10% DR Case, under high and low range cost assumptions.

- Assumes 5.3% discount rate for OTC repowering and LADWP operational costs, and 10% discount rate for other investments.

![High Range Assumptions](image1)

![Low Range Assumptions](image2)
The table below shows Case rankings by NPVs of total costs (2017 $ billions) for various levels of carbon price assumption.

- Assumes Lower Range cost assumptions and 5.3% / 10% discount rate.

<table>
<thead>
<tr>
<th>Base</th>
<th>2x</th>
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<th>6x</th>
<th>8x</th>
<th>10x</th>
<th>12x</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$14.28</td>
<td>$16.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$14.33</td>
<td>$16.77</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$14.35</td>
<td>$16.78</td>
<td>$21.17</td>
<td>$24.93</td>
<td>$28.60</td>
<td>$32.28</td>
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<td>$14.40</td>
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<td>$21.25</td>
<td>$25.30</td>
<td>$29.44</td>
<td>$33.58</td>
</tr>
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<td>$21.60</td>
<td>$25.94</td>
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<tr>
<td></td>
<td>$14.80</td>
<td>$17.00</td>
<td>$21.63</td>
<td>$26.49</td>
<td>$31.09</td>
<td>$35.54</td>
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<tr>
<td></td>
<td>$14.82</td>
<td>$17.03</td>
<td>$21.75</td>
<td>$26.65</td>
<td>$31.35</td>
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<tr>
<td></td>
<td>$14.96</td>
<td>B</td>
<td>$17.14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$15.03</td>
<td>$17.26</td>
<td>$22.04</td>
<td>$26.72</td>
<td>$31.60</td>
<td>$36.53</td>
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<tr>
<td></td>
<td>$15.09</td>
<td>VIII</td>
<td>$17.26</td>
<td>$22.07</td>
<td>$26.77</td>
<td>$31.77</td>
</tr>
<tr>
<td></td>
<td>$15.24</td>
<td>VI</td>
<td>$17.37</td>
<td>$22.18</td>
<td>$27.09</td>
<td>$32.01</td>
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<tr>
<td></td>
<td>$15.53</td>
<td>XII</td>
<td>$17.57</td>
<td>$22.20</td>
<td>$27.18</td>
<td>$32.29</td>
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<tr>
<td></td>
<td>$15.73</td>
<td>VII</td>
<td>$17.76</td>
<td>$22.39</td>
<td>$27.63</td>
<td>$32.87</td>
</tr>
</tbody>
</table>

Values based on Brattle calculation using Higher Range Cost assumptions based cash flow data.
Appendix: OTC Study Results Observations

Carbon Reduction Cost Analysis - 1/2

Observation: Per unit cost of carbon reduction is also lower for higher number Cases (with less OTC repowering).

Note: GHG emissions reflect total emissions over the 22-year study period.
Per unit carbon reduction costs ($/metric ton) for each Case are shown in the table below for various levels of carbon price assumption.

- Cases are listed in order of lowest cost of reduction to highest cost of reduction.
- Yellow highlighting indicates when the order of Cases switches.

<table>
<thead>
<tr>
<th></th>
<th>2x</th>
<th>4x</th>
<th>6x</th>
<th>8x</th>
<th>10x</th>
<th>12x</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon Price Assumptions ($/metric ton emissions)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>$18.66</td>
<td>$37.32</td>
<td>$74.64</td>
<td>$111.96</td>
<td>$149.28</td>
<td>$186.59</td>
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<td>2027</td>
<td>$23.79</td>
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<td>$95.16</td>
<td>$142.74</td>
<td>$190.32</td>
<td>$237.90</td>
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<tr>
<td>2036</td>
<td>$36.90</td>
<td>$73.81</td>
<td>$147.62</td>
<td>$221.42</td>
<td>$295.23</td>
<td>$369.04</td>
</tr>
</tbody>
</table>

**Ranking of Cases by per Unit Carbon Reduction Cost (2017 $/metric ton reduction)**

<table>
<thead>
<tr>
<th>Case</th>
<th>2x</th>
<th>4x</th>
<th>6x</th>
<th>8x</th>
<th>10x</th>
<th>12x</th>
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<tbody>
<tr>
<td>X</td>
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<tr>
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<td>$206.86</td>
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<tr>
<td>VIII</td>
<td>$208.21</td>
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<tr>
<td>XI</td>
<td>$224.48</td>
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<tr>
<td>VI</td>
<td>$230.56</td>
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<td>XII</td>
<td>$233.21</td>
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</tr>
<tr>
<td>Baseline (B)</td>
<td>$240.71</td>
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<td></td>
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</tr>
<tr>
<td>I</td>
<td>$244.17</td>
<td>$281.87</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>$245.27</td>
<td>$284.44</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>$245.67</td>
<td>$284.73</td>
<td></td>
<td></td>
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<tr>
<td>VII</td>
<td>$245.78</td>
<td>$285.00</td>
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<tr>
<td>IV</td>
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<td>V</td>
<td>$268.13</td>
<td>$307.73</td>
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</tbody>
</table>

Values based on Brattle calculation using Higher Range Cost assumptions based cash flow data.
Appendix: OTC Study Results Observations

Scattergood Repowering Alternatives

Scattergood @ 5% CF + Storage

Scattergood @ 5% CF + Rooftop PVs
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