Low Carbon Grid Study Phase I **Utility Revenue Requirement Analysis**

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Scope of this analysis

This utility revenue requirement analysis:

- Is an addendum to NREL's production cost modeling results for Phase I of the LCGS
- Computes the revenue requirement and rate impact of the study's Target Case by comparing 2030 revenue requirements of the Target Case and the Baseline Case
- Computes the cost of carbon reductions by calculating the change in revenue requirement* per metric ton (MT) of carbon reduced. This is added to the $31.41/MT carbon price used within NREL's model.
- Uses public capital cost and financing assumptions extrapolated to 2030 with no "technology breakthroughs" in costs or major disruptive changes in natural gas or carbon prices.
- Provides a snapshot of the ratepayer impacts of a strategy to decarbonize California's grid in 2030. Phase II will provide a more detailed rate analysis.

**Note: "change in revenue requirement" in this presentation always refers to the difference in revenue requirement between the Target and Baseline Cases, i.e. the annualized cost of implementing the Target Case relative to a business as usual scenario*

Methodology

1) Compute costs associated with Target Case (relative to Baseline Case):
    a. Find total investment required to construct Target Case, relative to Baseline; levelize[1] the capital expenditure to find annualized cost in the year 2030
    b. Find annual fixed operation and maintenance (O&M) costs associated with additional generation in Target Case
    c. Find levelized costs associated with energy efficiency (EE) and demand response (DR) programs
    d. Calculate resource adequacy (RA) payments to DR and gas
2) Compute savings associated with Target Case (relative to Baseline Case):
    a. Fuel cost savings in Target Case
    b. Variable O&M savings in Target Case
    c. Carbon credit savings associated with Target Case
3) Subtract savings from costs to find net revenue requirement in 2030 associated with the Target Case
4) Use the net revenue requirement to calculate $/MWh energy used in 2030 and $/MT of carbon reduced

[1]*Capital costs levelized using a spreadsheet tool developed by E3 for WECC.*

Assumptions: Baseline Case

Baseline Case is NOT a "do nothing" case

Assumes: Continued implementation of existing greenhouse gas (GHG) reduction policies and programs, such as 33% RPS, CPUC storage mandate, and efficiency programs. Assumes retirement of Diablo Canyon when license expires.

- See next slide for details

Adds: New gas to meet minimum planning reserve margin of 15% in 2030

Achieves: ~17 MMT GHG emissions reductions in 2030 from 2012 actual levels

- This is an 18% decrease in emissions from 2012 levels

Assumptions: Baseline Case Details

Baseline Case includes:

- Compliance with 33% RPS mandate with current protocols
  - Adds 7 TWh RPS energy between 2020 and 2030
- Continuation of present trends in deployment of customer-sited (non-RPS) PV
  - Customer-sited PV produces ~6% of retail sales in 2030
- California electricity load growth due to electrification of transportation and building sectors
- Successful execution of aggressive energy efficiency programs by both IOUs and POUs
- Successful execution of current CPUC initiatives in small-scale storage, demand response, and QF/CHP Settlement
  - Assumes reasonable growth in small-scale storage after CPUC mandate period ends, but no new bulk storage is added after 2020
- Transformation of California's natural gas fleet consistent with State Water Resources Control Board once-through cooling (OTC) requirements and 2012 CPUC LTPP procurement authorization
- Success and expansion of current Energy Imbalance Market (EIM) initiative within California and with other Western States
- Other Western States meeting their current RPS/GHG targets
- Coal retirements that have been announced and planned resource additions occurring throughout WECC by 2030

Significant differences between Target and Baseline Case

- **Renewables:** A balanced portfolio of 80 TWh of new renewables and associated transmission is added in the Target Case.
  - Baseline Case adds 7 TWh of new utility-scale renewables by 2030 (amount needed to maintain 33% RPS)
  - Difference in energy supply made up by higher capacity factors of gas fleet in Baseline Case
- **Customer-sited PV:** Deployment reaches 10% of retail sales in Target Case.
  - Deployment is 6% in Baseline Case.
- **Storage:** 2200 MW of additional new bulk storage included in Target Case.
  - No new bulk storage in Baseline Case
- **Energy Efficiency:** Incremental energy efficiency added according to the CEC's High Mid incremental efficiency forecast in Target Case. Assumes more aggressive Codes and Standards efforts by CEC than in the Baseline Case.
  - Mid CEC incremental efficiency case assumed in Baseline Case
- **Demand Response:** Assumes "best current practices" for DR (e.g., similar to PJM) in Target Case, as opposed to "significant improvement" from today in Baseline Case.

Note - total renewable energy in each portfolio:
2020: 97 TWh; Baseline (2030): 110 TWh; Target (2030): 177 TWh

Investment portfolio, 2020 – 2030: supply-side

Portfolio Element	2020 zero-carbon portfolio[1]	Incremental additions, 2020-2030			
		Baseline Case		Target Case	
	Capacity, MW	Capacity, MW	Capex, $million	Capacity, MW	Capex, $million
Biomass	1,348	-	-	269	1,220
Geothermal	2,744	-	-	1,500	9,260
Wholesale solar PV	9,950	4,110	10,400	5,445	14,470
Solar Thermal	1,400	-	-	1,670	8,680
Wind	10,400	-	-	9,480	17,540
CC Gas		600	740	-	-
Storage	4,800	175[2]	700	2,375	4,270
Transmission			250		2,600
Total			**12,090**		**57,940**

[1]*Based on 2012 LTPP. This includes contracted renewables both in and out of state.*

[2]*Represents small-scale storage built after 2020 (same in both cases).*

Investment portfolio, 2020 – 2030: demand-side

Portfolio Element	2020 portfolio	Incremental additions, 2020-2030		Difference in levelized utility program costs (in 2030)
		Baseline Case	Target Case	
	Capacity, MW	Capacity, MW	Capacity, MW	
Customer Sited PV	6,090	2,800	8,500	
Energy Efficiency	4,350[1]	4,350	8,950	$155 million
Demand Response	2,176[2]	2,624	7,424	$25 million[3]

[1]Average of "mid" and "high mid" CEC efficiency cases plus POU incremental efficiency
[2]CPUC 2014 LTPP planning assumption (for the year 2024)
[3]Placeholder for Phase I, will analyze in Phase II

Principal cost and financing assumptions

- Capital cost and fixed O&M cost estimates based on E3 recommendations to WECC. These were tailored to the Target and Baseline Case portfolios and assumed to be installed in 2025 (for a "weighted average" online date)[1]
- Used E3 Levelized Fixed Cost (LFC) spreadsheet model developed for WECC to generate LFC associated with difference between Baseline and Target Case in 2030. Input assumptions included:
  - Capital expenditure and fixed O&M from above
  - Default financing assumptions from WECC LFC model unless specified otherwise (see WACC discussion on next slide)
    - Generation assumed to be developed with independent power producer (IPP) power purchase agreements (PPAs)
    - Pumped hydro storage assumed to be IOU rate based
    - Compressed air energy storage (CAES) and gas CC assumed to be POU rate based
    - Transmission assumed to be FERC rate based

Other assumptions

- Did not attempt to determine or attribute net costs of distribution system expenditures to different customer-side investments.
- DR and EE programs run and financed similar to today (e.g., rebates, shareholder incentives)
- CA Resource Adequacy (RA) price of $40/kw-yr

[1]Note that these default assumptions generally are higher than current capital costs, especially for wind and solar

Weighted average cost of capital (WACC) assumptions

- WACC is a single number that encompasses the cost of financing, including interest rate on debt, market returns on equity, and available leverage.
- All of the above depend on macroeconomic factors, perceived portfolio attractiveness of investments in "clean energy," investor risk tolerance, and individual project parameters.
- WACC forecast is nearly as critical to future renewable levelized cost of energy (LCOE) as gas price forecast is to future new gas LCOE.
- Relevant published estimates:
  - E3/WECC: ~7.4% differentiated by technology
  - CEC: ~6.8% differentiated by technology
- Used a "middle-ground" WACC point estimate of 7.0% flat for all technologies as best point estimate.[1]
- Phase II will use standard analysis techniques to study a range of possibilities.

[1]Note that this is significantly higher than WACC today -- especially for PV investments. Implicit assumption is that generic interest rates return to "normal" and financing climate for clean energy sector is mature.

Phase I Estimated 2030 Revenue Requirement Impact

2030 Revenue Requirement: Target Case – Baseline Case, $million		
Levelized Capex[1]		4,391
Fixed O&M		690
EE Program Charges		155
DR Program Charges		25
RA payments to DR providers[2]		192
RA payments to gas fleet[2]		(124)
	Total	**5,329**
2030 Production Cost Savings: Target Case – Baseline Case, $million		
Fuel[3]		4,235
Variable O&M/start & shutdown[3]		371
CO_2 emissions credits[3]		946
	Total	**5,551**

[1]Levelized capital expenditure calculated using capital expenditures from slide 7 and calculating the associated LFC using assumptions on slides 9 and 10.

[2]Capacity payments calculated by: taking the difference between DR use or peak gas dispatch between the Target and Baseline Cases and multiplying by $40/kw-yr RA payment (slide 9)

[3]Production cost savings are outputs of NREL's production cost model (see slide 22 of NREL presentation)

Rate Impact/Cost of Carbon Reduced

Net ratepayer savings of Target Case (*relative to Baseline*)	**~$200 million in 2030**
Rate impact	**~- $0.6/MWh** ~0.4% of current retail rates
Carbon reductions in Target Case (*relative to Baseline*)	38.9 $MMTCO_2e/yr$
Added savings associated with reductions (*~$200M/38.9 MMT*)	~$5/MT
Total cost of carbon reductions to California ratepayers[1]	**~$25/MT**

Based on capital costs, program expenditures, and fuel and carbon cost savings, implementing the Target Case costs California ratepayers about $200 million less in 2030 than the Baseline Case.

[1]*Total cost of carbon = carbon price in 2030 (slide 2) + added cost of reductions*