DOCKETED	
Docket Number:	19-IEPR-07
Project Title:	Electricity Sector
TN #:	229908
Document Title:	Value and Demand for Offshore Wind in California
Description:	Presentation by Sandy Hull, Energy and Environmental Economics
Filer:	Raquel Kravitz
Organization:	Energy and Environmental Economics
Submitter Role:	Public
Submission Date:	10/1/2019 3:58:23 PM
Docketed Date:	10/1/2019

Value and Demand for Offshore Wind in California

IEPR Commissioner Workshop on Offshore Wind

October 3, 2019

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Topics covered

+ **Long-term clean energy needs and value of offshore wind**

+ **Comparison of recent study findings:**
  - Castle Wind
  - Ocean Protection Council (OPC) study with UC-Berkeley

+ **Areas for further research**

Disclaimer required by the California Public Utilities Commission

"Findings in this report have been prepared by E3 for Castle Wind and the California OPC. This report is separate from and unrelated to any work E3 is doing for the California Public Utilities Commission. While E3 provided technical support to Castle Wind and the OPC in preparation of this report, E3 does not endorse any specific policy or regulatory measures as a result of this analysis. The California Public Utilities Commission did not participate in this project and does not endorse the conclusions presented in this report.

E3 utilized the RESOLVE model developed for the CPUC's 2017-2018 Integrated Resource Planning proceeding (R.16-02-007) in preparation of this report. At the direction of Castle Wind, E3 has made specific modifications to the CPUC RESOLVE model for the purpose of conducting the analysis described herein. The modifications are summarized in the table below.

Summary of Modifications made to the CPUC 2018 IRP RESOLVE model:

Modification	Purpose
Generic California offshore wind resource added to renewable supply curve	To evaluate the buildout and potential cost savings associated with offshore wind as a resource option
Solar, wind, and battery storage resource costs modified	To provide more up-to-date points of comparison when modeling offshore wind avoided costs in the future

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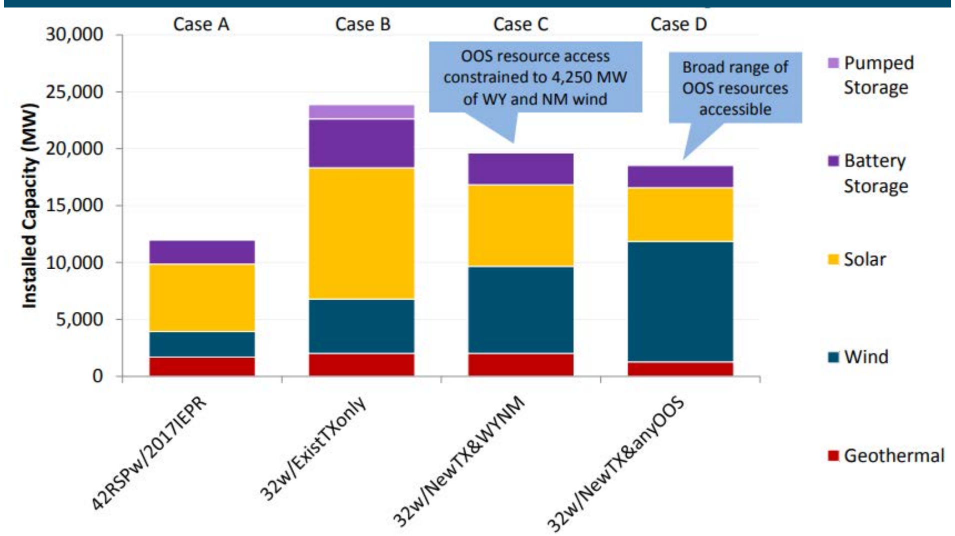
Long-term clean energy needs and value of offshore wind

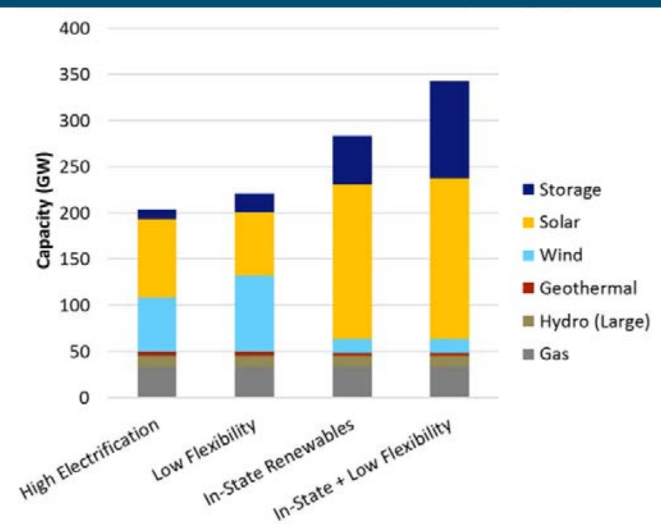
Recent planning studies forecast scale of California's future clean energy needs

+ **Economywide GHG emission targets of 40% reduction below 1990 levels by 2030 and 80% by 2050 will require increasingly ambitious investments in clean energy to replace existing fossil energy generation while serving increasing demand from EVs and electrified buildings**
  - Recent studies indicate that up to 20 GW of wind, solar, storage, and geothermal may be needed by 2030
  - 100-200 GW of new renewables and storage may be needed by 2050 to power increasingly electrified economy

2030 Scenarios for Transmission Planning Process (CPUC 2017-18 IRP)



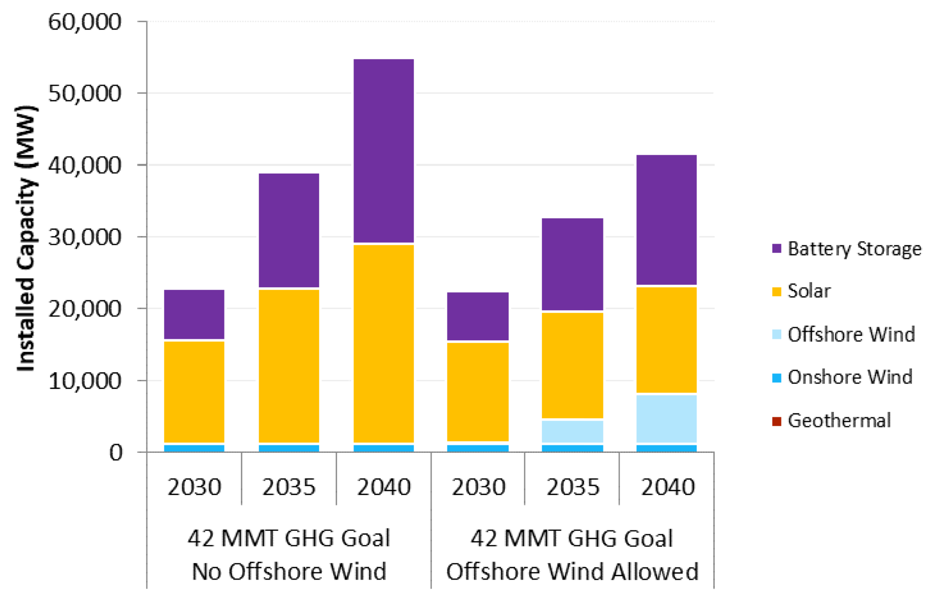
2050 Scenarios for CEC Deep Decarbonization Study



Limited resource options lead to increasing value for diversity in future

- **Given limited onshore wind and geothermal resource potentials, CA would have to rely almost entirely on solar and storage to meet long-term policy goals, which becomes increasingly expensive in the future**
  - Large volumes of storage are needed to decarbonize power supply in non-solar hours
- **What is the value of diversity from alternative resource options like offshore wind?**
  - Modeling shows that offshore wind may significantly reduce overall system costs under existing CA policies
  - Each MW of offshore wind offsets need for ~1.7 MW of solar, 1.1 MW of batteries in 2040

Long-Term Resource Additions w/ and w/out Offshore Wind

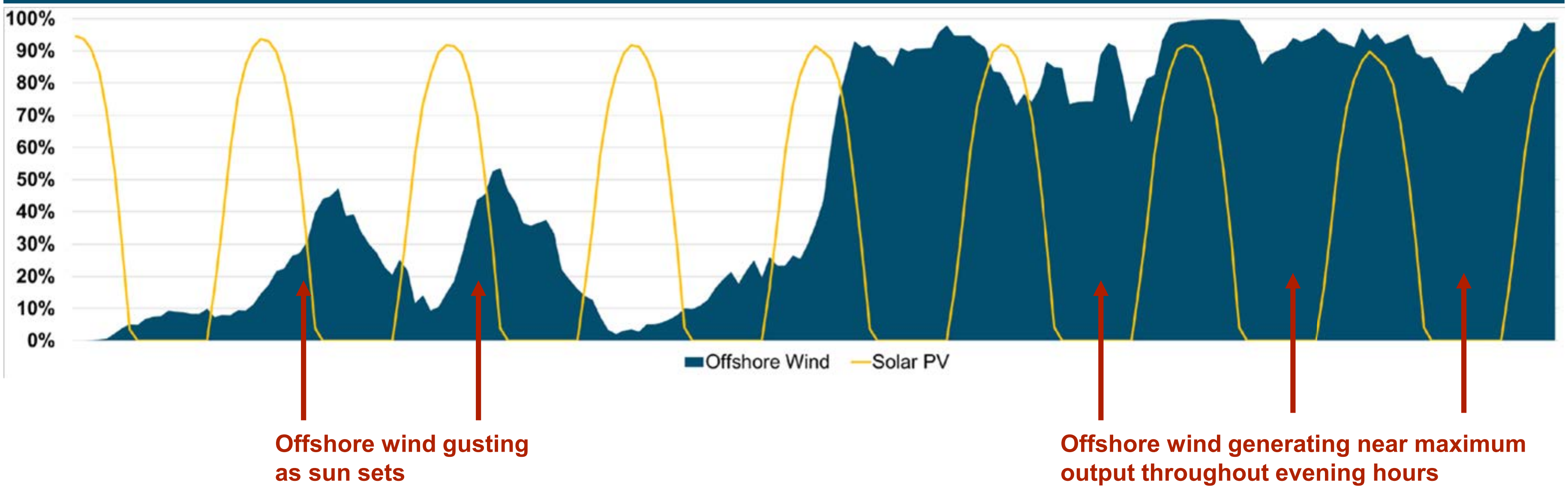


RESOLVE modeling shows that offshore wind could greatly reduce reliance on solar and storage in 2030 and beyond

Offshore wind's value comes from its generation in non-solar hours

+ **Large solar penetration in CA means that gas generation and resulting GHG emissions are more concentrated in evening hours**
  - Building enough battery storage to serve evening loads with solar would be costly
+ **Offshore wind tends to pick up and generate most energy in evening hours when output is most valuable**

Offshore Wind vs. Solar Generation: Simulated Week



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Recent E3 studies on offshore wind in California

E3 has performed two of the first studies on the value of offshore wind in California

+ **Both studies analyzed the role of offshore wind on the California grid using recent versions of the RESOLVE capacity expansion model using a different approach:**
  - Castle Wind study assumed a cost for OSW and modeled system portfolios and savings at that cost
  - OPC study did not model OSW costs explicitly, but instead focused on value to grid at different levels of capacity deployment and compared those to a range of estimated future costs

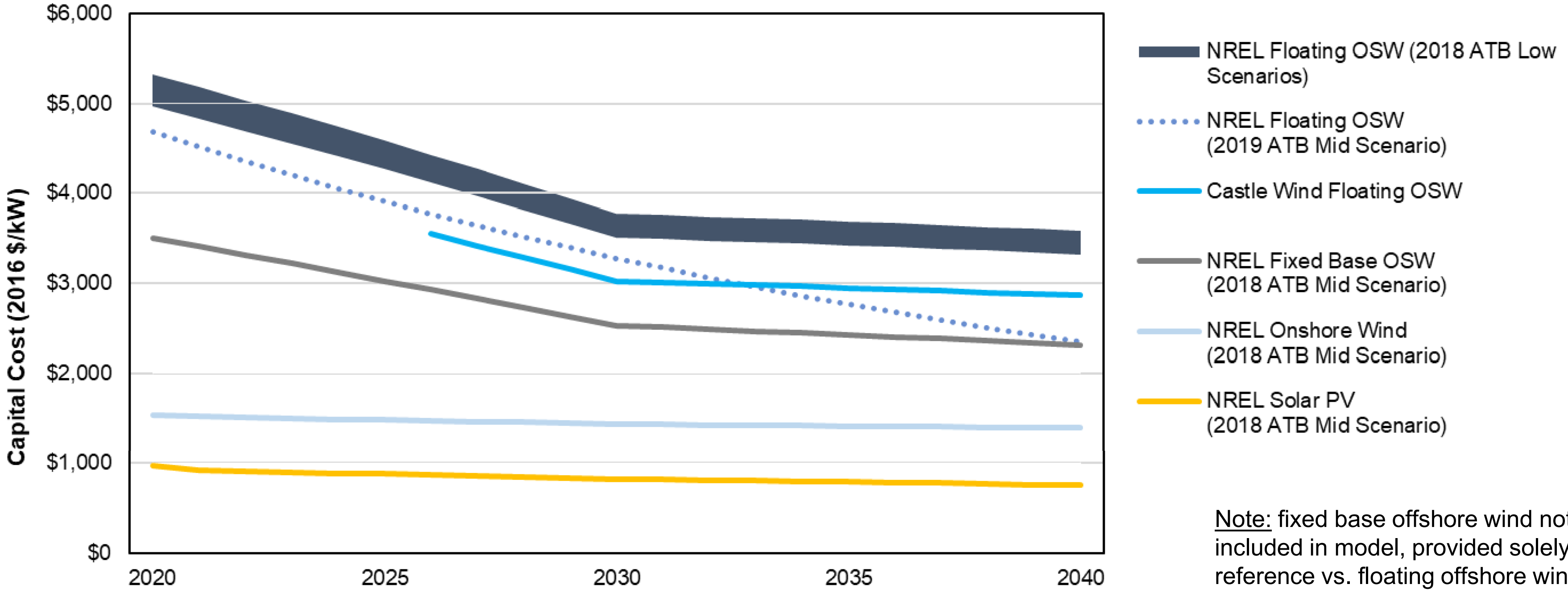
+ **Castle Wind report: July 2019**
  - Model: 2017-18 CPUC IRP RESOLVE model, plus cost assumptions provided by Castle Wind
  - Goal: to determine the economic value of OSW for CA (and kick start the dialog on the benefits of including OSW in the state's long-term energy planning efforts)
  - Results: potential economic demand for offshore wind and associated grid savings

+ **California OPC report (co-authored with UC-Berkeley Labor Center): September 2019**
  - Model: CEC RESOLVE model from Deep Decarbonization study
  - Goal: to characterize California's offshore wind resources and estimate the benefits of grid integration
  - Results: identification and quantification of offshore wind resource zones in CA and valuation of offshore wind delivered on the CA grid

Offshore wind capital cost assumptions
Castle Wind study

- **Castle Wind capital cost assumptions were approximately 14% lower than the 2018 NREL ATB's Low cost scenario for floating offshore wind with a similar 52% CF**
  - Castle Wind cost assumptions are based on next generation 12 MW turbines
- **Castle Wind capital costs modeled with same % cost decline as NREL estimates**
  - Latest NREL cost forecasts are 9% higher than Castle Wind study in 2030, 18% lower by 2040

Capital Cost Forecast Assumptions Modeled



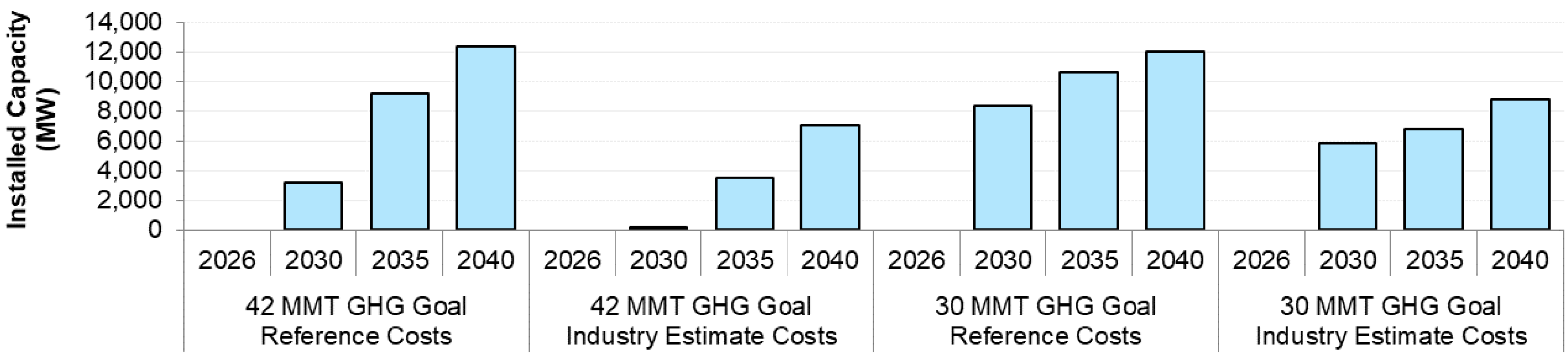
Note: fixed base offshore wind not included in model, provided solely for reference vs. floating offshore wind costs

Offshore wind demand and grid savings

Castle Wind study

- **For Castle Wind study, E3 modeled the optimal amount of offshore wind and associated savings under several cost and GHG reduction scenarios**
  - Assumed generic wind profile for Morro Bay area, no Tx limitations
- **Offshore wind was selected as part of the least-cost portfolio in all scenarios modeled, with at least 3.5 GW of capacity identified as optimal by 2035 in every sensitivity**
  - Optimal offshore wind capacity and timing of buildout depends heavily on GHG targets
- **Offshore wind appears to be cost-competitive by around 2030 timeframe in each scenario**
- **Approximately 7-9 GW of offshore wind appears optimal by 2040 using latest cost estimates for offshore wind (provided by Castle Wind) and other resources (from NREL)**
- **Offshore wind has the potential to save CA ratepayers millions of dollars per year in the 2030s vs. model scenarios with no offshore wind, up to $2 billion total in NPV terms**

Cumulative Offshore Wind Capacity Additions Selected by RESOLVE (MW)



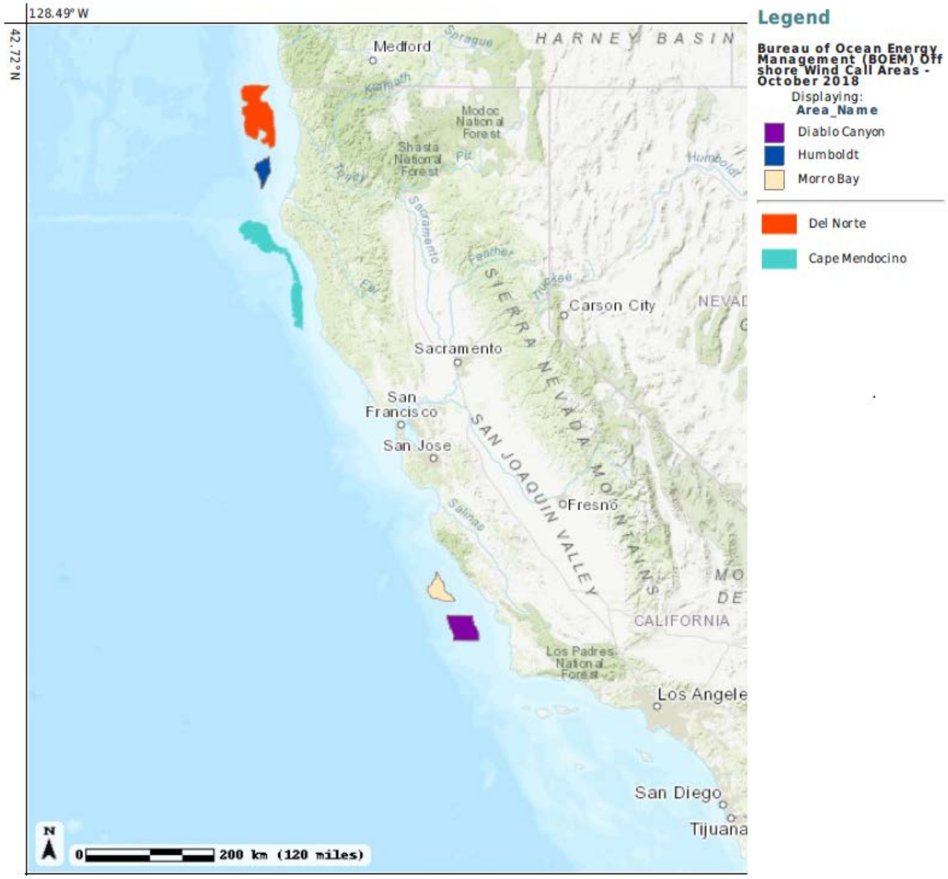
California's offshore wind resources
OPC study

+ **Wind resource zones were defined and characterized based on:**
  - NREL and BOEM studies
  - Marine sanctuaries and Navy exclusion zones
  - Wind speeds
  - Water depth
  - Distance from shore

Offshore Wind Resource Zone	Resource Zone Area (Sq. km)	Resource Potential (MW)	Simulated Capacity Factor (%)
Diablo Canyon	1,441	4,324	46%
Morro Bay	806	2,419	55%
Humboldt Bay	536	1,607	51%
*Del Norte**	*2,201*	*6,604*	*51%*
*Cape Mendocino**	*2,072*	*6,216*	*53%*
Total	7,051	21,171	

**Resource zones identified in addition to existing BOEM call areas*

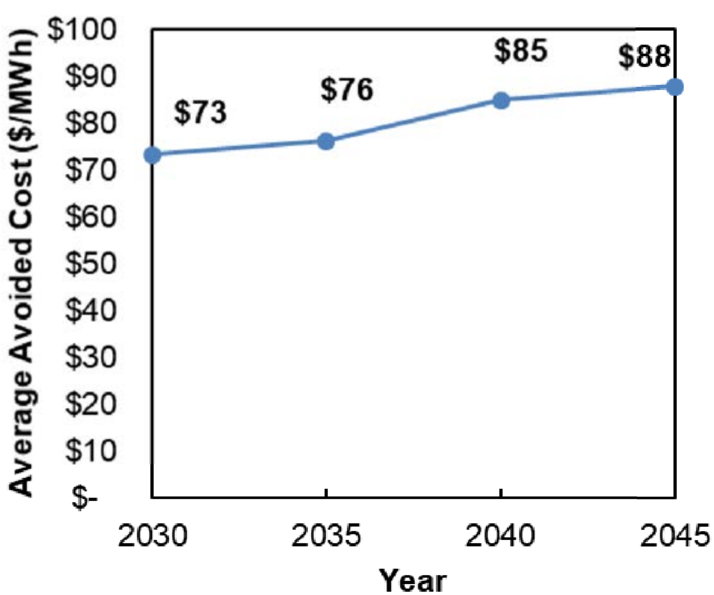
Offshore Wind Zones Identified in Study



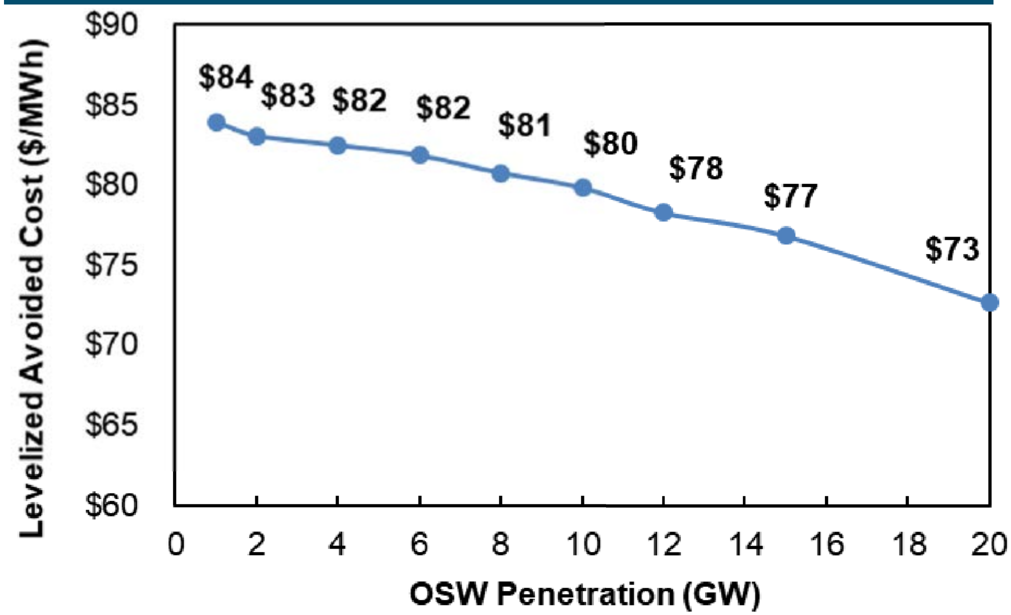
Value of offshore wind to the CA grid
OPC study

+ Offshore wind was valued by modeling the avoided costs if it was deployed on the CA grid
+ The value of offshore wind increases over time as CA's GHG targets become more stringent
+ While the value of offshore wind declines at greater penetrations, its average value is robust at $80+/MWh at scales up to 10 GW
+ The LCOE of floating offshore wind is expected to fall to $65-$80/MWh by the mid-to-late 2020s according to the latest NREL forecasts, which would make offshore wind cost-competitive in CA

Forecasted Value of Offshore Wind
$/MWh



Levelized 20-Year Value of Offshore Wind by Total Capacity Deployed
$/MWh, 2030-2050

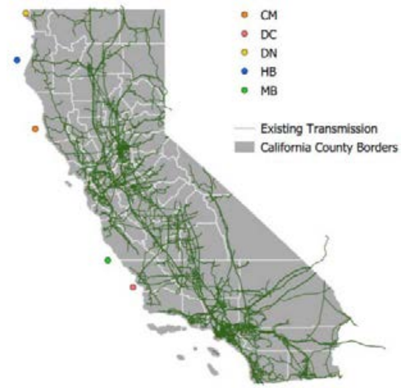


Areas for further research

Initial modeling suggests offshore wind merits more in-depth planning studies

- **Offshore wind should be studied in more depth to assess, plan for, and enable future development opportunities**
- **Topics of additional studies should include:**
  - Siting issues: development areas, associated transmission needs, and costs
    - Offshore wind transmission study similar to Renewable Energy Transmission Initiative (RETI) could characterize Tx opportunities
  - Wind speed and generation profiles
    - Data for more potential wind sites over more years would enable more precise modeling of generation value
  - California-specific cost forecasts for floating offshore wind generation

Existing California transmission infrastructure



Example offshore wind generation profile

Month \ Hour of Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	43%	44%	44%	45%	45%	43%	42%	42%	42%	41%	41%	40%	40%	40%	39%	38%	37%	37%	36%	37%	38%	39%	42%	42%
2	50%	50%	51%	51%	52%	51%	51%	50%	48%	48%	47%	47%	46%	45%	46%	45%	44%	43%	43%	43%	43%	46%	47%	48%
3	57%	58%	59%	60%	60%	60%	59%	59%	57%	56%	55%	55%	55%	55%	53%	52%	51%	49%	48%	49%	50%	52%	54%	56%
4	64%	65%	67%	67%	68%	68%	67%	65%	65%	63%	62%	63%	62%	61%	60%	59%	58%	57%	56%	57%	58%	60%	61%	63%
5	70%	72%	72%	73%	74%	74%	73%	72%	71%	71%	70%	69%	69%	68%	66%	65%	64%	63%	61%	62%	63%	64%	66%	68%
6	64%	66%	68%	68%	69%	69%	69%	68%	67%	67%	67%	67%	66%	64%	63%	61%	60%	58%	57%	57%	58%	59%	61%	62%
7	52%	55%	57%	58%	58%	57%	55%	54%	54%	54%	53%	52%	50%	50%	48%	47%	45%	44%	43%	42%	42%	44%	46%	48%
8	54%	57%	59%	61%	61%	61%	59%	58%	57%	56%	56%	56%	55%	53%	50%	49%	47%	45%	45%	45%	45%	46%	49%	52%
9	49%	51%	53%	54%	54%	53%	50%	49%	48%	48%	49%	48%	47%	45%	43%	42%	41%	40%	38%	38%	40%	41%	44%	46%
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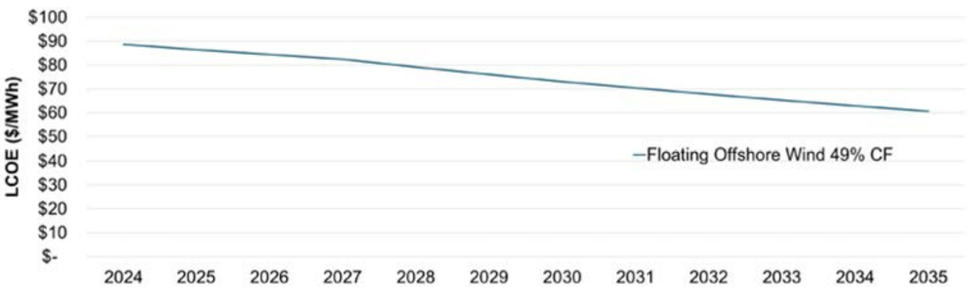
11	49%	50%	51%	53%	52%	50%	49%	47%	45%	44%	44%	43%	43%	43%	43%	42%	40%	40%	39%	39%	41%	43%	44%	46%
12	43%	44%	44%	45%	44%	43%	43%	42%	41%	41%	41%	40%	40%	40%	39%	38%	38%	38%	38%	39%	40%	40%	41%	42%

Forecasted floating offshore wind costs



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Thank you

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Appendix 1: Castle Wind study

Clean energy resources will each play different roles

- **Early RPS goals have been met primarily with large investments in onshore wind and solar. However, new technologies may help meet long-term targets**
- **<u>Onshore wind</u> is cost-effective, but remaining resource potential is limited and subject to transmission constraints**
  - Limited remaining resource potential for new onshore wind power in CA
  - Limited transmission capacity for new out-of-state wind power

- **<u>Solar</u> offers decreasing grid value as it saturates the daylight hours and requires increasing costs to integrate and shift to evening hours**
  - Solar generation faces diminishing value due to oversupply and more frequent curtailment during daytime hours
  - Energy storage could store excess solar energy for use at night, but battery storage becomes increasingly expensive at levels needed for reliability under long-term decarbonization policies

- **<u>Geothermal, biomass, and other renewables</u> are generally more expensive and limited in potential or performance**

?

- **<u>Offshore wind</u> offers a potential new long-term supply option**
  - Offshore wind is widely deployed in Europe, declining rapidly in cost, and could have a role in meeting CA's long-term goals

What is the system value of offshore wind?

- **All resources must be evaluated based on system value relative to costs**
  - Does total system value justify total system costs? If so, rates will be lower

- **Offshore wind provides three key sources of system value**
  - Energy value
    - Avoided cost of displaced generation: e.g. fuel savings or reduced need for solar capacity
    - Coincidence with peak evening hours makes offshore wind particularly valuable
  - RPS/GHG reduction value
    - REC value, which is independent of time of generation. Around $15/MWh for PCC1 today
    - GHG value, which is reflected in energy prices via carbon cost for generators with emissions
  - Capacity value
    - System resource adequacy
    - Local resource adequacy
    - Flexible resource adequacy

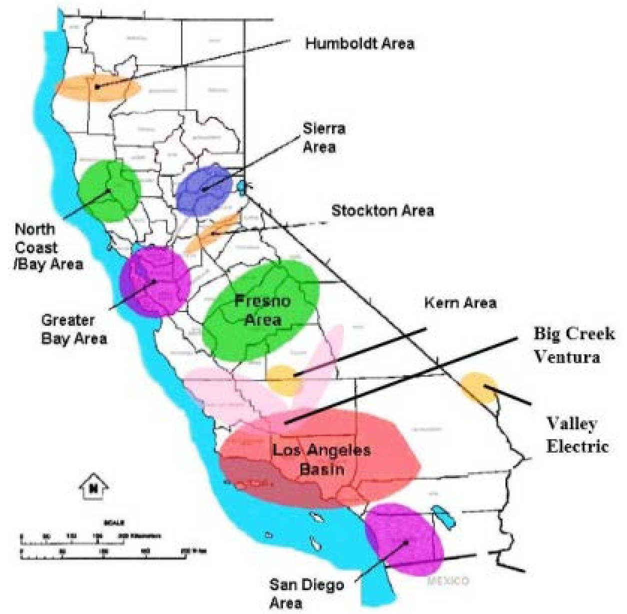
How are these values captured in RESOLVE?

- RESOLVE is a capacity expansion model that identifies the least-cost portfolio of generation resources, taking into account both capital costs and operating costs at the hourly level
- Energy and REC/GHG value: RESOLVE dispatches resources subject to operating costs as well as RPS and GHG constraints, which shape resource economics via shadow prices for RECs and carbon
  - For example, RESOLVE will identify the REC price needed to incentivize SB100 compliance or the carbon price needed to ensure that CA meets its GHG reduction goals
- Capacity value: RESOLVE uses estimates of the effective load carrying capability (ELCC) of variable resources like solar and wind to determine their Resource Adequacy (RA) contributions. RESOLVE builds portfolios to ensure that system RA needs are met and will calculate a shadow price on RA in cases where the system needs additional capacity for reliability
  - Local capacity value is not captured in RESOLVE. Offshore wind has the ability to provide local capacity as an additional value if delivered into constrained load pockets like the LA Basin

Additional potential value of offshore wind not captured in RESOLVE

- **California's local Resource Adequacy (RA) program identifies several transmission constrained load pockets with unique reliability needs**
- **Largest and most costly Local RA areas to serve coincide with large coastal population centers**
  - Los Angeles, San Diego, Greater Bay Area
- **Retiring Once-Through-Cooling (OTC) plants along coast provide valuable interconnection points for future offshore wind capacity that could provide Local RA value**
- **Local RA value is not captured in E3's RESOLVE modeling for Castle Wind, but provides an additional potential value stream for offshore wind interconnected within coastal load pockets in the future**

Local Resource Adequacy Areas in CAISO



System cost impact

- Offshore wind has the ability to reduce system costs to ratepayers by as much as $2 billion on an NPV basis in the 30 Mt GHG target scenario
- Annual savings as large as $200M in 2030 from 6 GW of offshore wind and $190M by 2040 from 9 GW of offshore wind in the 30 Mt GHG scenario

Annual System Costs Savings Over Time (Operating Costs Plus New Capital Costs) ($ Millions)

GHG Target Scenario	2026	2030	2035	2040	2019 NPV of Savings
42 Mt GHG Goal	$2	-$9	$39	$149	$881
30 Mt GHG Goal	-$22	$216	$164	$193	$1,964
Savings = Costs in Reference Case – Costs with Offshore Wind Allowed					

Note: all scenarios above run under Industry Estimate Costs scenario with no out-of-state wind

OSW capacity built under two cost scenarios

Cumulative Offshore Wind Capacity Selected by RESOLVE (GW)

GHG Target – OSW Cost	2026	2030	2035	2040
42 Mt – Reference Costs	-	3.2	9.2	12.4
42 Mt – Industry Estimate Costs	-	0.2	3.5	7.0
30 Mt – Reference Costs	-	8.3	10.6	12.0
30 Mt – Industry Estimate Costs	-	5.9	6.8	8.8

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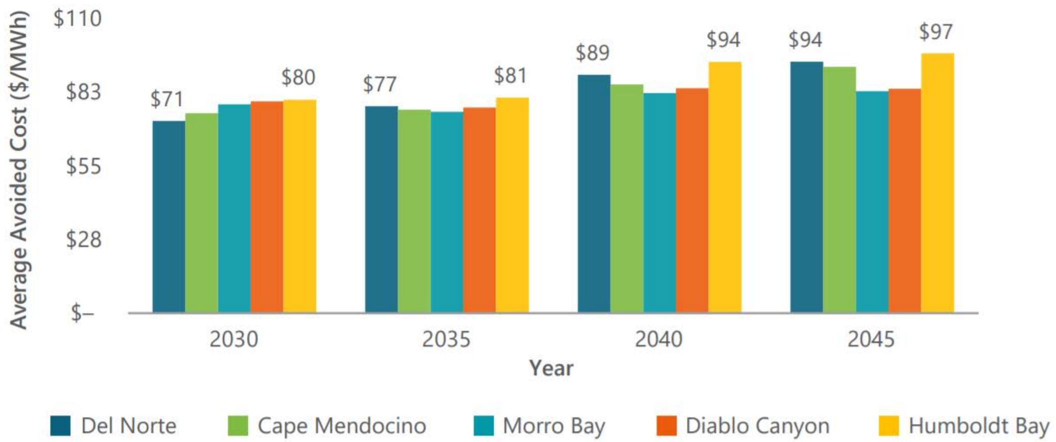
Appendix 2: OPC Study

Resource zone comparison

OPC study

+ **Several zones appear economic in the near term**

Average Value of Offshore Wind by Resource Zone and Year



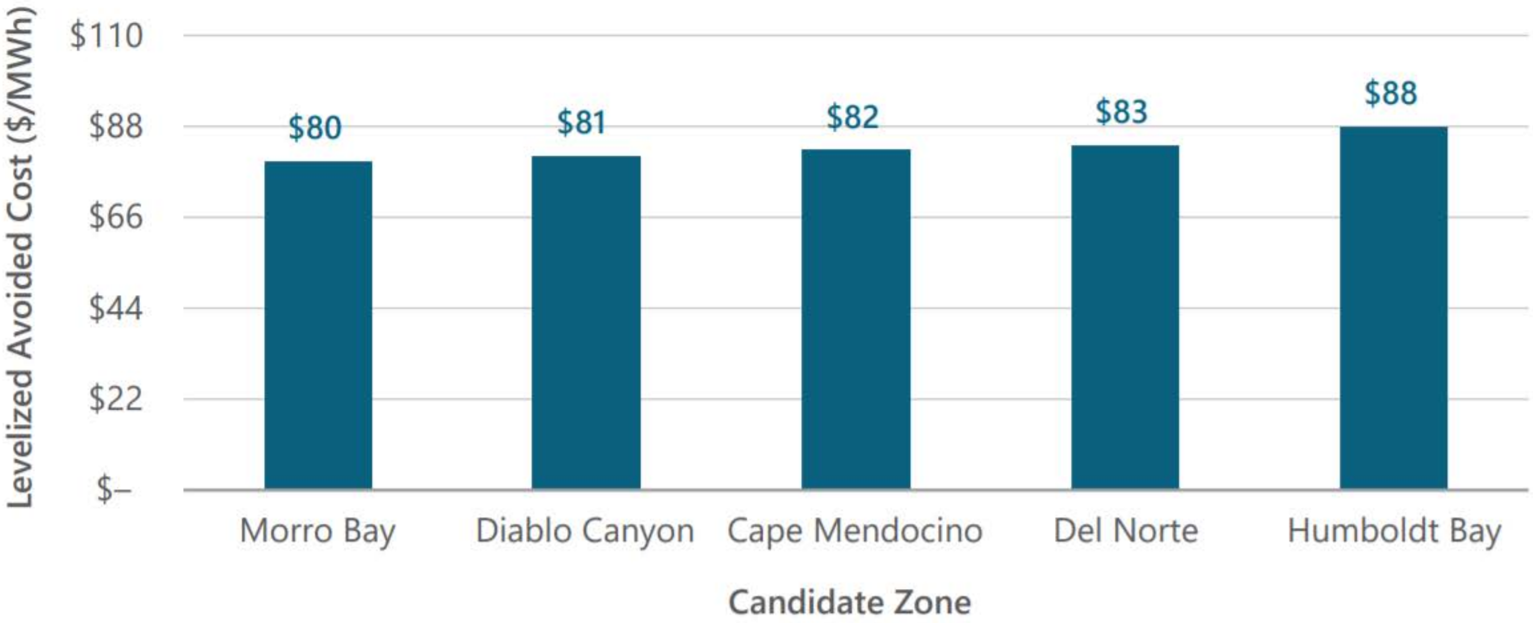
Offshore Wind Resource Zones	Simulated Capacity Factor	Average Avoided Cost 2030-50 LACE, 2 GW scale	2025-2030 Cost Range LCOE, NREL ATB+E3	Transmission Headroom
Morro Bay	55 percent	$80/MWh	$62 to $72/MWh	668 MW
Diablo Canyon	46 percent	$81/MWh	$74 to $88/MWh	3,933 MW
Humboldt Bay	51 percent	$88/MWh	$66 to $78/MWh	Minimal
Cape Mendocino	53 percent	$82/MWh	$65 to $76/MWh	Minimal
Del Norte	51 percent	$83/MWh	$66 to $78/MWh	Minimal

Levelized OSW project value by zone

OPC study

+ **Forecasted levelized value (avoided cost) by resource zone over 2030-50 project life in $/MWh**

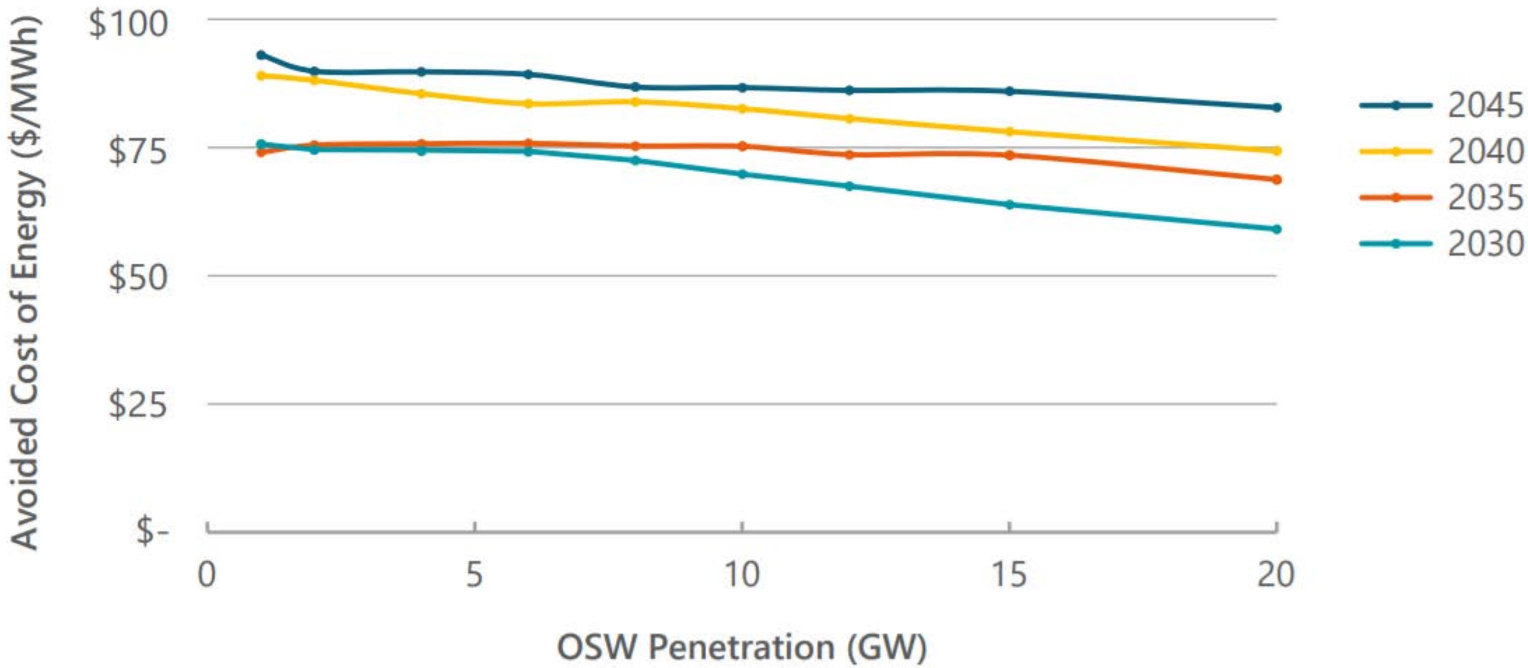
Average Value of Offshore Wind Declines At Higher Penetrations, but Increases over Time



Future value of OSW by capacity and year

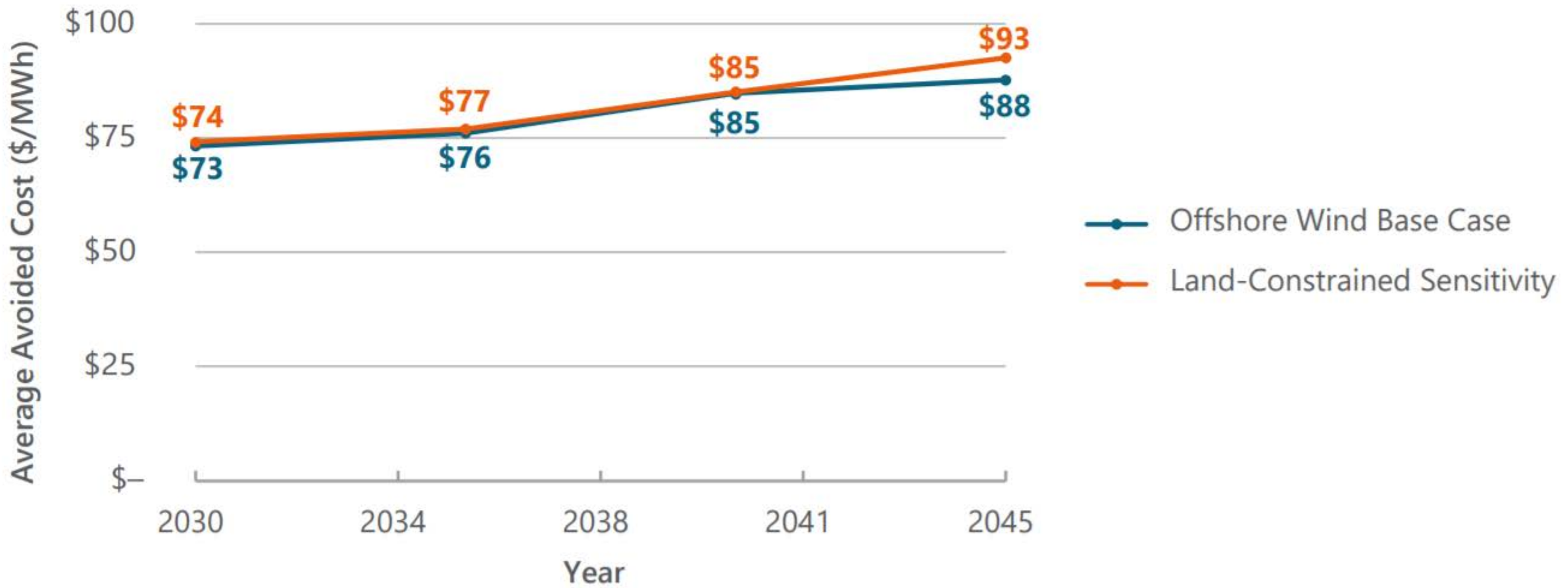
OPC study

Average Value of Offshore Wind Declines At Higher Penetrations, but Increases over Time



Sensitivity 1: Constrained solar potential
OPC study

Average Value of Offshore Wind is Higher if Land for Future Solar Development is Constrained

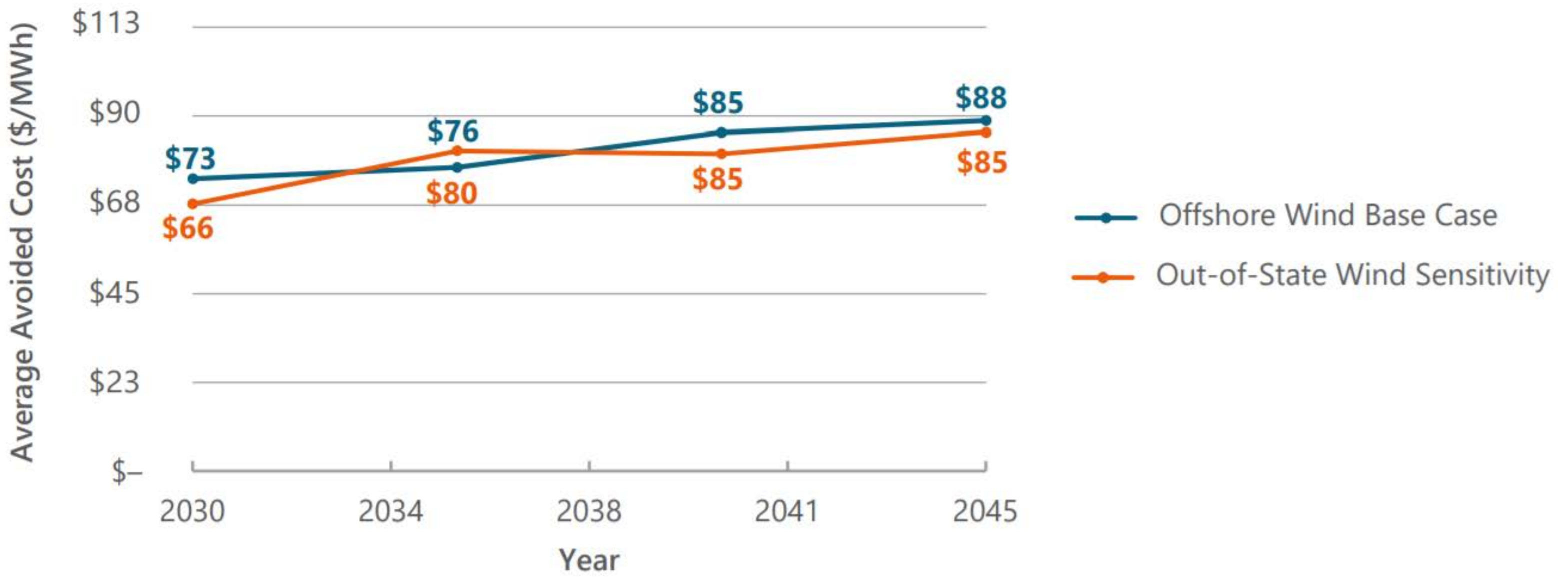


Sensitivity 2: Low solar/storage costs
OPC study

Average Value of Offshore Wind is Lower if Solar and Storage Costs are Lower than Forecasted

Sensitivity 3: Out-of-state wind potential
OPC study

Average Value of Offshore Wind is Lower if Out-of-State Wind Potential is Increased



Sensitivity 4: Accelerated GHG targets

OPC study

Average Value of Offshore Wind is Higher in Later Years if GHG Targets Are Accelerated