Key Findings

California has a long track record of leadership in combating climate change and achieving strong renewable energy goals. Floating offshore wind projects are being evaluated as a means of reaching the state's RPS and emission reduction targets. This report represents the first analysis of the impacts of floating offshore wind projects on GHG emissions in offshore waters along the California coast.

The result of this study confirms that floating offshore wind is a potential solution for California to significantly decrease GHG emissions associated with electricity production. This study identified key life cycle stages, components, and materials that have the the strongest contribution to GHG emissions and includes recommendations to mitigate their emissions.

Life Cycle Analysis

Floating Offshore Wind
Results demonstrate significant potential to decrease California's emissions.

Characterizing Emissions

Maximum GHG Emissions
92% less than natural gas.

GHG Emission Range
Comparable to nuclear & hydro.

Key Stages

Manufacturing
Generates the vast majority of GHG emissions.

Recycling
Potential to significantly decrease emissions.

Reducing Emissions

Greater Capacity Factor
More electricity production, thus less Life Cycle GHG Impact.

Longer Operational Life
More electricity produced in windfarm's life, thus less Life Cycle GHG Impact.

Key Components

Substructure & Turbine
41% and 36% of emissions.

Steel & Fossil Fuels
49% and 27% of emissions.

Recommendations

Environmental and Regulatory Benefits

Utilize floating offshore wind energy in California to:
— Achieve emission reduction targets and energy production goals.
— Improve air quality by reducing emissions associated with natural gas.

Mitigation Efforts

— Focus on manufacturing and recycling phases.
— Prioritize factors influencing capacity factor and operational lifetime of the wind farm.

Future Studies

— Evaluate impacts of floating offshore wind projects on California's electricity gridmix.
— Expand LCA scope to other environmental impacts of floating offshore wind projects.

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Further Information

For more on our project, accessing presentation material, and for further correspondence, please visit us at: *https://www.oceanwindproject.com* or feel free to contact us at: *gp-windfallca@bren.ucsb.edu*

Ocean Wind Project | Life Cycle Assessment of Greenhouse Gas Emissions for Floating Offshore Wind Energy in California

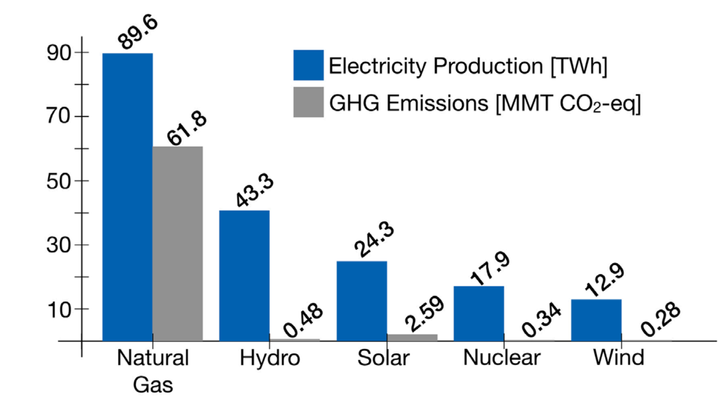
Authors: Jung-Il Bang, Cyrus Ma, Eric Tarantino, Alejandro Vela, Derek Yamane **Advisor:** Sangwon Suh, Ph.D
Client: Bureau of Ocean Energy Management

Project Summary

Given the large-scale renewable energy targets in California, floating offshore wind represents a new energy resource that can help the state meet this policy target. This study characterizes and assesses the greenhouse gas (GHG) emissions associated with the integration of offshore wind energy into California electricity markets. In comparison to other existing energy resources in California, our results show that the maximum GHG emissions from floating offshore wind is less than one-tenth the lowest estimated value of natural gas. These results imply that offshore wind has the potential to provide low-carbon electricity in California.

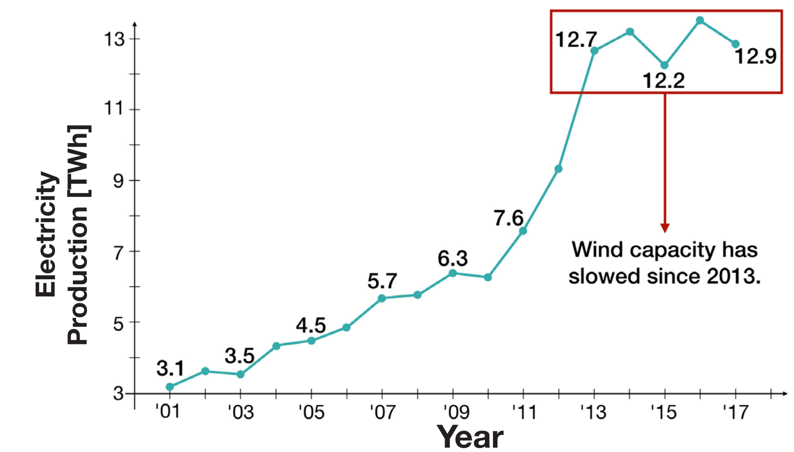
Background

California Electricity Production and GHG Emissions by Source in 2017



In California, Senate Bill 100 (est. 2018) requires 100% zerocarbon generated electricity throughout California by 2045. However, natural gas still represents the largest source of non-renewable electricity in the state, accounting for 43% of the total in-state power and 93% of the GHGs emitted from electricity generation in California.

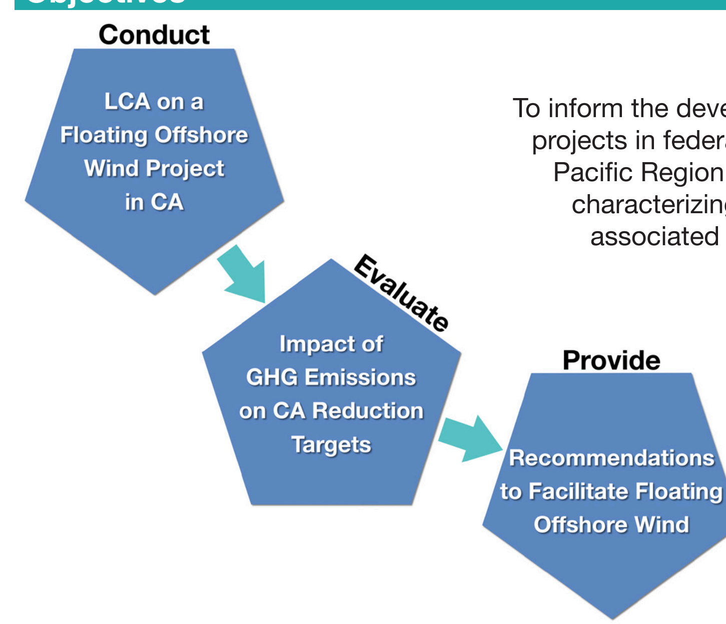
California Wind Energy Production by Year



Although California has one of the country's most aggressive Renewable Portfolio Standards (RPS), the growth of land-based wind power has stagnated over the last several years because of the land-use restrictions and limited in-land wind resources.

Floating offshore wind farms represents a renewable energy resource that can reduce natural gas consumption and help California meet its RPS target, complements solar power production.Due to California's deep offshore continental shelf, floating offshore wind platforms represent the most practical technology for offshore deployment.

Objectives



To inform the development of floating offshore wind projects in federal waters off California, BOEM Pacific Region has tasked the Bren School with characterizing and assessing the GHG emissions associated with floating offshore wind energy.

Approach

Life Cycle Assessment

Life cycle assessment (LCA) quantifies flows of resources and energy, as well as environmental impacts of a system (ISO 14044 Standards). LCA informs stakeholders of the implications of their choices for environmental quality and sustainability.

Floating Offshore Wind Project

Major Parameters

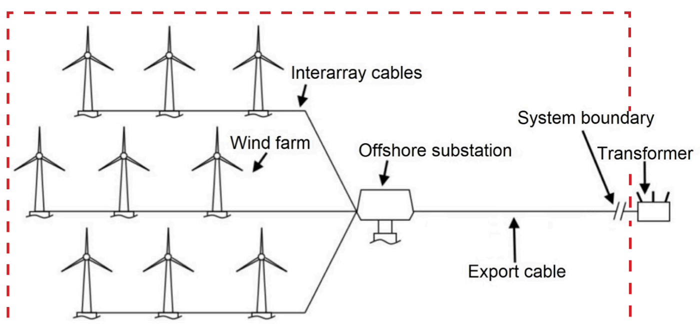
- Project Size: 600MW (75 x 8MW turbines with spar-buoy substructure)
- Turbine Size: 164 m rotor diameter, 105 m hub height
- Location: 35 km from electricity grid, 450 m water depth
- 50% capacity factor, 25 year operational life

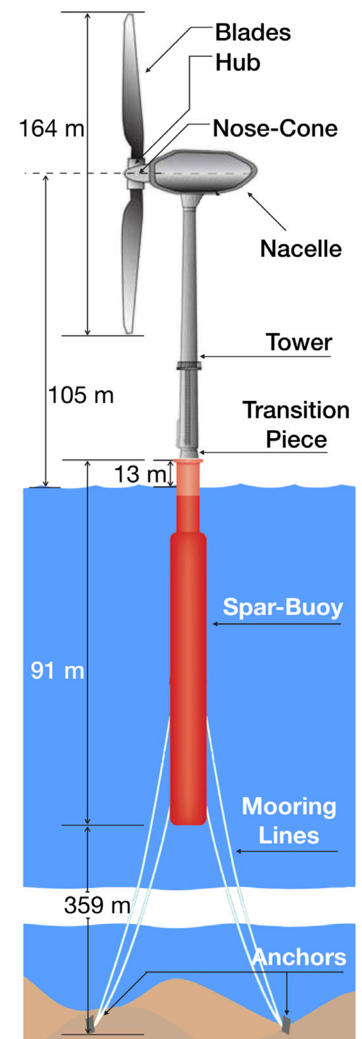
Unit of Measurement

Environmental impact in this LCA is measured by lifetime kilograms of CO_2 equivalent emissions per lifetime electricity generation in megawatt hours (kg CO_2-eq/MWh).

$$\text{Life Cycle GHG Impact} = \frac{CO_2 \text{ [kg } CO_2\text{-eq]}}{\text{[MWh]}}$$

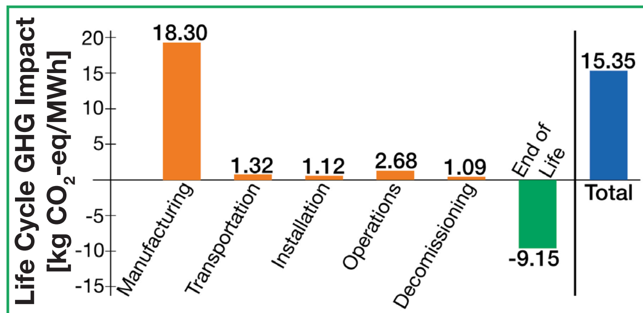
System Boundary





Results

Results Overview

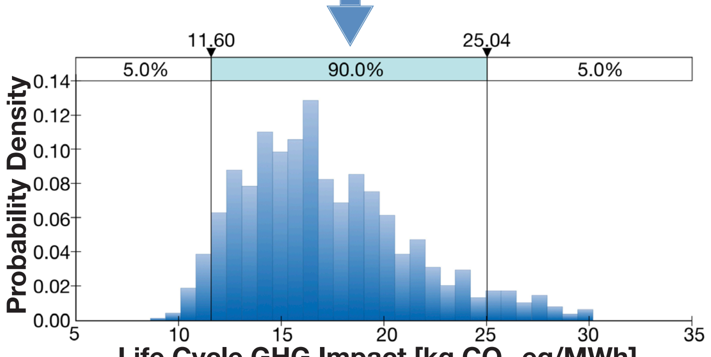


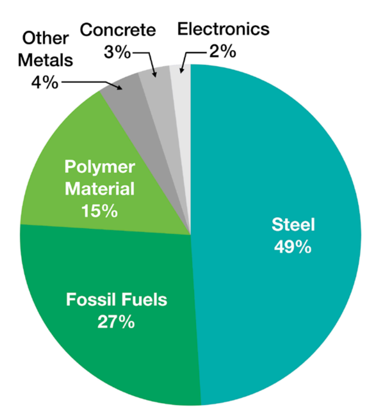
Life Cycle GHG Emissions

The model baseline scenario predicts total GHG emissions of 15.35 kg CO_2-eq/MWh.

Among life cycle stages, Manufacturing is the main contributor (18.3) followed by Operations (2.7) while End-of-Life contributes significant deductions (-9.2) through recycled materials and energy recovery. In Manufacturing, the substructure (41%) and turbine (36%) were identified as the major contributors.

Monte Carlo Simulation predicts an uncertainty range of 8.58 - 30.17 kg CO_2-eq/MWh, with 90% confidence ranging from 11.60 - 25.04 kg CO_2-eq/MWh.





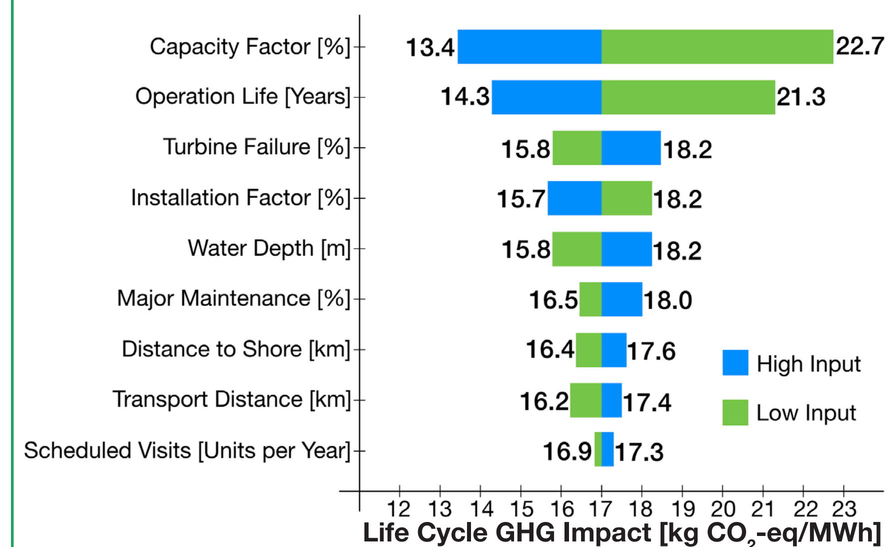
Materials

Steel is identified as the largest contributor (49%), followed by fossil fuels (27%), and polymer materials (15%).

Results

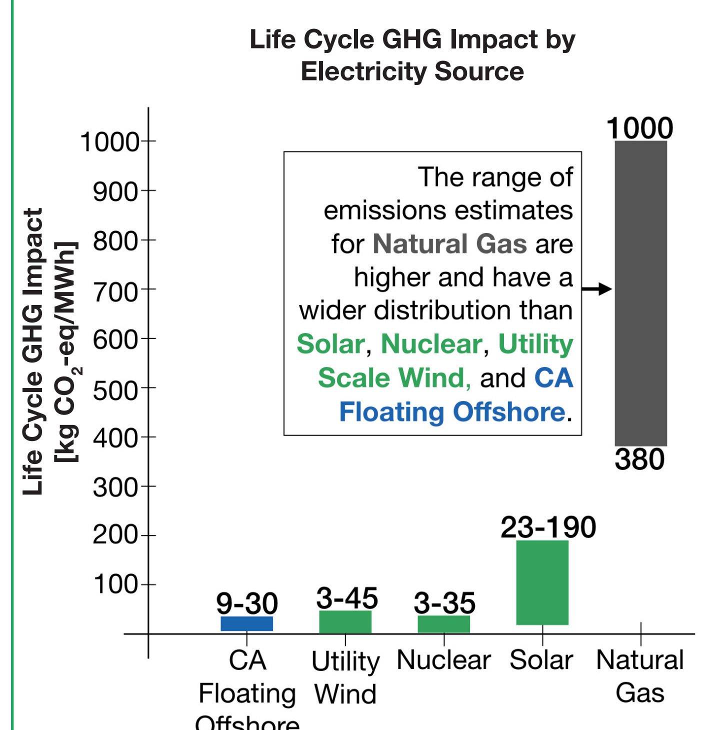
Sensitivity Analysis

The sensitivity analysis shows the influence that each of the nine analyzed parameters has on GHG emissions. These results indicate that the following mitigation measures could reduce emissions:



- Achieving a high capacity factor
  - High input (65%): 13.4
  - Low input (35%): 22.7
- Prioritizing quality to extend life
  - High input (35 years): 14.3
  - Low input (20 years): 21.3
- Reducing turbine failure
  - High input (10%): 18.2
  - Low input (2%): 15.8
- Installing turbines during optimal conditions
- Limiting water depth and distance to shore

Comparison with Other Energy Sources



Minimum estimates for **Natural Gas** emissions are higher than **Maximum** estimates for **Floating Offshore** by a factor of 10. These values demonstrate a significant opportunity for California to reduce its GHG emissions and help satisfy their energy production goals.

Compared to natural gas, a single 600 MW floating wind farm can potentially reduce emissions by 934 - 2,598 million kg of CO_2 equivalent/year. This is equal to at least:

- 105 million of gallons of gasoline consumed
- 198 thousand of vehicles driven for 1 year
- 15 million of tree seedlings grown for 10 years