### Approach

**Background**

California Electricity Production and GHG Emissions by Source in 2017

- **Electricity Production (TWh)**
- **GHG Emissions (Mt CO2-eq)**

![Graph showing California electricity production and GHG emissions by source.](image)

In California, Senate Bill 100 (est. 2018) requires 100% decarbonization of electricity production by 2045. This new requirement amplifies the importance of innovative renewable energy technologies, such as offshore wind.

**Objectives**

- **System Boundary:** Life-Cycle GHG Impact [kg CO2-eq/MWh].
- **Goal:** Reduce GHG emissions associated with electricity production by 2045.

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

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

**Approach**

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

**Floating Offshore Wind Project**

- **Capacity Factor:** 
- **Operation Life (Years):**
- **Turbine Failure Rate:**
- **Water Depth:**
- **Mega Watts per Substructure:**

**Unit of Measurement**

Environmental impact in this LCA is measured by lifetime kilograms of CO2 equivalent emissions per lifetime electricity generation in megawatt hours (kg CO2-eq/MWh).

**Life Cycle GHG Impact**

![Graph showing life cycle GHG impact by source.](image)

Life Cycle GHG Impact [kg CO2-eq/MWh]

- **Compared to Other Energy Sources:**
- **Impact of Deepest Wells:**
- **Low Input:**
- **High Input:**

**Results Overview**

**Life Cycle GHG Emissions**

The model baseline scenario predicts total GHG emissions of 13.35 kg CO2-eq/MWh.

Among life cycle stages, Manufacturing is the main contributor (53%) followed by Operations (27%) while End-of-Life contributes significant deductions (-9.2) through recycled materials and energy recovery. In Manufacturing, the subcategory (41%) and turbine (35%) were identified as the main contributors.

**Sensitivity Analysis**

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

- Achieving a high capacity factor
- Prioritizing quality to extend life
- Reducing turbine failure
- Limiting low input during optimal conditions
- Limiting water depth and distance to shore

**Results**

**Life Cycle GHG Impact by Electricity Source**

Minimum estimates for Natural Gas emissions are lower 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.

Minimum emissions are 23.190 kg CO2-eq/MWh, while maximum emissions are 13.35 kg CO2-eq/MWh.

**Comparison with Other Energy Sources**

- **Utility Offshore:**
- **Natural Gas:**
- **Spare Brakes:**

**Recommendations**

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**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 off 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 strongest contribution to GHG emissions and includes recommendations to mitigate their emissions.

**Characterizing Emissions**

- **Maximum GHG Emissions:**
- **Less fossil fuels:**

**Reducing Emissions**

- **Greater Capacity Factor:**
- **More efficient generation:**

**Longer Operational Life**

- **More electricity produced in windfarms:**

**Key Stages**

- **Manufacturing:**
- **Generating the vast majority of GHG emissions:**

**Key Components**

- **Substructure & Turbine:**
- **Steel & Fossil Fuels:**

**Recycling**

- **Potential to significantly decrease emissions:**

**Future Studies**

- **Evaluate impacts of floating offshore wind projects on California’s electricity grid:**
- **Expand LCA scope to other environmental impacts of offshore wind projects:**

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**More Electricity Produced in Windfarm’s Life**

- **Greater capacity factor:**
- **Reducing emissions:**

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**Recommendations**

- **Focus on manufacturing and recycling phases:**
- **Prioritize factors influencing capacity factor and operational lifetime of the wind farm:**

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**Further Information**

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