Presentations for October 7, 2021 Board of Directors Meeting
Item 8: WETA Zero Emission Study Update
Study Goals

“Develop a plan to transition ferry operations on San Francisco Bay to zero-emission vessels”

- How much power do we need?
- Where will it come from?
- When do we need it?
- How much will it cost?
- How do we pay for it?

Emphasis on the use of electric propulsion systems and resolving the technical and regulatory barriers for the shore side infrastructure
Stakeholders Engaged
Stage 1
Baselining
Collect and process data on operations, vessels and terminals to define their constraints and opportunities

Stage 2
Optioneering
Develop solutions and assess their attributes and drawbacks to select optimal direction

Stage 3
Blueprint & Strategy
Lay out an actionable path to progress to procurement, design and delivery of electrified ferry service
Study Schedule

Vessel Side

- Baselining & data collection
- Develop Analysis Tools
- Preliminary Analysis
- Optioneering
- Blueprint

Shoreside

- Stakeholder Outreach
- Preliminary Capacity Analysis
- Blueprint
- Optioneering
- CEC Funds Released
- Today

Project Start

Aug 2022
Sept 2022
Oct 2022
Nov 2022
Dec 2022
Jan '22
Feb 2023
Mar 2023
Apr 2023
May 2023
Jun 2023
Jul 2023
Vessel Side Progress Update

**Vessel Side Work - Stage 1**

- Baselining & data collection
- Develop Analysis Tools
- Preliminary Analysis
- Optioneering
- Blueprint
- CEC Funds Released
- Stakeholder Outreach
- Preliminary Capacity Analysis
- Blueprint

**Shoreside**
Global Zero Emission Ferry Fleet *

* Vessels currently in service based on readily available information

- Hydrogen Vessels
- Battery Electric Vessels

Regions:
- Europe
- North America
- Asia
- Oceania
**Energy Sources**

- All propulsion options have strengths and weaknesses
- Careful route definition and analysis is required to determine the best match
- Battery Electric is initial focus per the CEC Study
- Hydrogen Electric provides a zero emissions “bridging” solution where Battery Electric is impractical

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### Electric Propulsion

<table>
<thead>
<tr>
<th>Battery</th>
<th>Hydrogen Fuel Cell</th>
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<tbody>
<tr>
<td>Vessel Emissions</td>
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<td>Overall Energy Efficiency</td>
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<tr>
<td>Range</td>
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<td>High Speed Capability</td>
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<td>Safety</td>
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<td>Technology Maturity</td>
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<td>Vessel Cost</td>
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<td>Vessel Maintenance Cost</td>
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<td>Infrastructure Cost</td>
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<td>“Fuel” Cost</td>
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### ICE* Propulsion

<table>
<thead>
<tr>
<th>Diesel</th>
<th>Hydrogen</th>
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<tr>
<td>Vessel Emissions</td>
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* Internal Combustion Engine

** This chart is a general representation of propulsion tradeoffs which may differ per geographical location
Data Collection

**Vessel Data Collected**

- Detailed Vessel Metrics
- Performance characteristics, speed vs power vs weight vs fuel burn
- Viability of Electric Conversion:
  - Remaining Lifespan
  - Structural Design Limits (How much weight and space margin do we have to install this equipment?)

**Route Data Collected**

- Develop a database of existing and planned routes. For each route, determine:
  - Load Profile
  - Daily Timetables
  - Route Constraints
  - Expected Growth
- Assess operational profiles for energy usage, speed sensitivity, and timetable sensitivity
WETA Ferry System Analysis

WETA’s complex service involves **A LOT OF VARIABLES!**

- How much energy is currently consumed on each route segment and what is the sweet spot for speed vs. power consumed vs passengers moved?
- What is the impact of extended dockside charging time?
- Is interlining possible or practical during a transition to electric?
- What impact does speed vs passenger capacity have on power consumed?

This required the development of some WETA specific **RAPID ANALYSIS TOOLS**
**Route Analyzer Tool**

Create a user-friendly tool to rapidly configure and optimize energy used on each route

**Enables user to:**

- Build a route from a dropdown library of route segments
- Select a vessel (current fleet and user defined)
- Adjust route parameters (speed, dock maneuverability, leg distances)

**Output:**

- Energy used
- Battery sizing
- Charging power required at each stop
- Transportation Efficiency metrics
- Diesel used - for calibration

### Trip Summary:

<table>
<thead>
<tr>
<th>Length (mi)</th>
<th>Speed (kts)</th>
<th>Time (min)</th>
<th>Fuel Consumption (gal)</th>
<th>Battery Consumption (kWh)</th>
<th>Trip Summary (Min)</th>
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</thead>
<tbody>
<tr>
<td>13.0</td>
<td>58.0</td>
<td>75.5</td>
<td>15:15</td>
<td>75.5</td>
<td>79%</td>
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### Outputs

<table>
<thead>
<tr>
<th>Route Segment</th>
<th>Length</th>
<th>Speed</th>
<th>Time</th>
<th>Propulsive Power Required</th>
<th>Fuel Consumption</th>
<th>Battery Consumption (Electric)</th>
<th>Cumulative On Time</th>
<th>Cumulative Off Time</th>
<th>SOC</th>
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### Logs

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<thead>
<tr>
<th>Log</th>
<th>Start Position</th>
<th>End Position</th>
<th>Total Distance</th>
<th>Unrestricted Transit Speed</th>
<th>Inner Harbor Transit Speed</th>
<th>Number of Passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Downtown</td>
<td>Oakland</td>
<td>6.4 mi</td>
<td>13.0 13.0 13.0 13.0</td>
<td>13.0 13.0 13.0 13.0</td>
<td>6.4</td>
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<tr>
<td>2</td>
<td>Oakland</td>
<td>Alameda Main Street</td>
<td>0.9 mi</td>
<td>6.3 6.3 6.3 6.3</td>
<td>6.3 6.3 6.3 6.3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Alameda Main Street</td>
<td>Downtown</td>
<td>5.7 mi</td>
<td>18.6 18.6 18.6 18.6</td>
<td>18.6 18.6 18.6 18.6</td>
<td>5.7</td>
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Fleet Analysis Tool

Rapidly determine the power required at each terminal

Receives inputs directly from the Route Analyzer tool

- Contains a graphical schedule builder
- Automatically updates real time systemwide energy demands at any given minute
- Exports an energy demand profile at each terminal to support shoreside infrastructure analysis

Weekday Ferry Building Power Demand

![Power Demand Chart](chart.png)
Shoreside Progress Update

Vessel Side

- Baselining & data collection
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Shoreside

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Shoreside Work - Stage 1
Shoreside Overview

Stage 1 - Baselining
- Existing Infrastructure
- Local Grid Context
- Space Constraints
- Ferry Requirements

Stage 2 - Optioneering & Optimizing
- Design Options
- Phasing Options
- Utility Engagement
- Vessel & Scheduling

Optimization Metrics
- Economic Metrics
- Emission Metrics
- Policy Compliance
- Service Provision
- Resilience Tests

Stage 3 - Blueprint
Transition Roadmap
Existing Electrical Connections and Design

Excluding central bay all terminals predicted to require substantive grid connection upgrades and the addition of resilience measures for transition. These will be costly.

Local Grid Context

High variability in the grid context of the different terminals. In particular Downtown is of high concern.

Space constraints assessment

Opportunities for solar, batteries and back up power reserves are being assessed by evaluating space availability.
Baselining – Terminal Assessment

Highly constrained grid with costly upgrades

Constrained grid with reasonable cost upgrades

Unconstrained grid with opportunities

- SF Ferry Building
- Richmond
- Alameda Seaplane
- Oakland
- South SF
- Central Bay Maintenance
- Alameda Main Street
- Mission Bay
- Berkeley
- Harbor Bay
- Treasure Island
- Redwood City

Potential Solar

Uncertain
Preliminary Roadmap
Phased Implementation

• Initial analysis points to four phases of implementation

• These will be refined during the next stage of the project
Phased Implementation

Phase 1 - Inner Central Bay
TI, Mission Bay, Pier 41, SFFB
Phased Implementation

Phase 2 – Central Bay
Oakland, Alameda, Berkeley
Phased Implementation

Phase 3 – Long Run Central Bay
Harbor Bay, South SF, Richmond
Phased Implementation

Phase 4 – Long Runs
Vallejo / Carquinez / Redwood City
Next Steps
Next Steps – Iterative Optioneering & Optimizing

Analysis & Optimization

- Route Analyzer Tool
- Fleet Analyzer Tool
- Arup Energy Optimization Platform

Stakeholders Input
- Utilities
- Regional Agencies
- Technology Providers

Scenario Development

Technical Inputs
- Ferry Parameters
- Terminal Parameters
- Routing Parameters

Results for each scenario
- Economic Performance
- Emission Performance
- Quality of Service Provision
- Transportation Efficiency
- Technical details & phasing
Next Steps – Iterative Optioneering & Optimizing

Rerun multiple scenarios for each phase

Answers to our study questions

- How much power do we need and where?
- What is the phasing for implementation?
- How much will it cost year by year?
- How do we pay for it?
Thank You