Pacific Marine Expo
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ENERGY AUDITS
Guidance for Small Alaska Fishing Vessels

Presented by
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Presentation Outline

- What are Energy Audits?
  - Purpose, Steps, Terms, Outcomes
  - Levels 1, 2, and 3 – Feasibility of Each
  - Energy Conservation Opportunities (ECOs)

- Energy Consumption vs. Energy Conservation
  - Bad News: Where Does the Energy Go?
  - Good News: ECOs and other NA/ME Stuff

- Example EA Calculations & Potential ECOs
  - 47' Troller / Longliner

- Financial Analysis

- Wrap-Up

- Questions??
Energy Audit

- **Energy Audit – Purpose & Goal**
  - Identify operations, equipment, and systems that waste energy (fuel/electricity), during the course of a vessel performing its mission
  
  - Identify opportunities to reduce energy consumption, and provide financial analyses of these opportunities
  
  - Reduce Operating Costs by Reducing FO Consumed
Energy Audit

- Energy Audit Steps and Terms
  - Level 1
    - Gather Information
      - Drawings, Equipment, E-1 line, Operations, and Mission
      - Operator Interview
    - Walk through Audit - Discuss "Low Hanging Fruit" with crew
      - No cost to implement
      - No significant inconvenience to implement
      - Provide immediate reductions in energy use
    - Identify Potential Large Paybacks (ECOs / ECIs)
Energy Audit Steps, cont.

- **Level 2 (Builds on Level 1)**
  - In Depth Vessel Survey – Energy Records & Measurements
    - Direct Observation During Vessel Operations
    - Fuel Meters, Fuel Logs, Utility Records
    - Power Logging Instruments and Software
  
  - Establish **Operational Profile & Energy Maps**
    - Analyze Information and Data (Incl. Operations)
      - FO burned
      - Amps / Voltage / kW;
      - GPM / PSIG
      - Temperatures, Pressures, Arrangements
      - Time

  - Develop **ECOs**
Energy Audit Steps, cont.

- **Energy Conservation Opportunities (ECOs)**
  - Quantifies Energy Saved (kWh and gallons FO)
  - Quantifies Energy Savings ($'s)
  - Economic Analysis Determines Priorities

- **Develop Energy Analysis Report/Present Findings**
  - (Levels 2 and 3)

- **Level 3 (Builds on Level's 1 & 2)**
  - Follow up and Support Implementation
  - Research / Evaluate ECIs
  - Future Design Changes
Feasibility of Energy Audits

- **Walk through Energy Audit (Level 1)**
  - Provides immediate benefit
  - Determine cost/suitability of conducting a more complex Energy Audit (Level 2 or 3)

- **For a single small vessel (fishing, tug, other..)**
  - Cost of conducting Level 2 Energy Audit *rarely* provides sufficient ROI if only conducted on a single vessel
  - Best ROI applied to a class

- **For a medium or larger sized vessel (>150')**
  - Level 2 Energy Audit *almost always* provides sufficient ROI to justify costs for a single vessel
Propulsion / Generator Engine Energy Consumption - The Bad News

23% EXHAUST

30% COOLING WATER

10% LUBE OIL

1% RADIATION

3% GEAR AND BEARINGS

33% SHAFT POWER
After the Heat, Where does it all go?

Propellers, Gears, Bearings
- **Good** Propellers: 55% - 65% efficient
- Gears: 97% - 98% efficient
- Bearings: 98% - 99%

.......And Then.......
More Naval Architecture Stuff
(Even More Bad News)

- **Resistance**
  - Wave Making Resistance – (Bow and Stern)
  - Frictional Resistance
    - Speed Component - (Goes up when you speed up)
    - Roughness Coefficient
      - Hull Cleanliness
  - Appendage Resistance (Struts, chocks, stabilizers, rudder, keel coolers, etc…)
    - Frictional
    - Wave

- **Now for the Good News!**
Energy Audit

- Each energy unit saved through efficiency improvement saves 3 energy units of fuel use
(EA) Energy Conservation Opportunities (ECOs)

- Operational Reviews
  - Vessel Speed……Routes……Timing
- Turning off Power
- Fuel Monitoring / Measuring
- Lights
  - Sensors / Power Off; HFE Ballasts; Incandescent vs. CFR vs. LED
- Waste Heat Recovery
- "Cold Ironing" – Use of Shore-Power
- Hull Cleanliness (0%-3% Reduction in Resistance)
- Air Compressors (See Common Air Compressor ECOs)
- Insulation
  - Type, Condition, Thickness
  - Refrigeration, HVAC, Potable Water
  - Payback Period is most often very short (<1 year)
ECOs, cont

- Cavitating Pumps – Poor Piping System Design
- HVAC Analysis
- Premium Efficiency Electric Motors and Controllers
  - VFDs
  - PLCs
- Belt Drives
- Engine / Equipment Maintenance
- "Right Sizing" Engines / Generators / Motors / Hydraulics to loads
- Hull Design ECOs: (Reductions in Resistance)
  - CFD Analysis (5%-20%)
    - Line, Skegs, Rolling Chocks, Rudder, Struts, Appendages, Gear
    - Bulbous Bow (5%-10%)
    - Propeller and/or Nozzle Optimization (5%-10%)
(Common) Air Compressor ECOs

- Use Synthetic Lubricants in Air Compressors
- Check and Verify cut in / cut out Settings
- Reduce Air Pressure
- Eliminate / Reduce Air Leaks
- Recover Compressor Waste Heat
- Use Outside (cooler) Air for Compressor Intake
- Install Larger Header Line in Compressed Air System
- Switch to High Efficiency Belts
47' Troller /Longliner
47' Troller / Longliner

- Operational Profiles – 3 Fisheries
  - Trolling for Salmon/Delivering Fresh Iced Product
  - Trolling for Salmon/Freezing Product Onboard
  - Longline for Sablefish and Halibut

- Equipment Size and Ratings/ Systems' Arrangements & Power Consumptions
- Transit Time, Speed, RPMs, FO Burned
- Fishing Time, Speed, RPMs, FO Burned
- Stand By Time – Equipment / Systems Power Consumptions
- Lay Up Time - Equipment / Systems Power Consumptions
- ........and so on......
47' Troller / Longliner, cont.

- **Vessel "Energy Map"**
  - High Propulsion, Refrigeration, and Hydraulic Loads
    - Hydraulic Loads drive Refrigeration Loads
    - No FO meters – Looking into it
  - Very Light 110 v Electrical Loads (Hotel)
  - 12 and 24 volt Electrical Systems
    - Belt Drives, Alternators, Inverters, Batteries
  - Good Insulation (Holds and Exhaust)
  - No HVAC / AC
  - ER temp is 80°F - 85°F; 12V fans (Good temp)
  - Diesel Stove for Heat – 2 gal./day
  - Uses Waste Heat for Hot Water
  - Custom Propeller – Cupped Trailing edges
  - Rolling Chocks & Para Vane Stabilizers
  - And so on…………………………
Potential ECOs

- **"Low Hanging Fruit"**
  - Speed Reduction and other Operational Modifications
  - Modified Rolling Chocks (shorten or remove entirely)

- **Longer Term "Potential" ECOs & ECIs (Requiring more in-depth review)**
  - Reduced Hull Resistance
  - Shore Power for Refrigeration
  - Modified Hydraulics (to reduce heat and gain efficiency)
  - Waste Heat Recovery (vessel heating and adsorption/absorption based refrigeration systems)
  - Belt Drive & Alternator Mods  (*Marginally Viable ……*)
For small changes in speed, an approximation of the change in fuel consumption per nautical mile can be made using the following equation:

\[
\text{New fuel consumption} = \text{original fuel consumption} \times \left( \frac{\text{new vessel speed}}{\text{original vessel speed}} \right)^2
\]

Fuel consumption curve for a 13.1 m purse seiner

<table>
<thead>
<tr>
<th>Speed (kt)</th>
<th>Reduction in speed</th>
<th>Reduction in fuel consumption in (litres/nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.8</td>
<td></td>
<td>0%</td>
</tr>
<tr>
<td>7.02</td>
<td>10%</td>
<td>28%</td>
</tr>
<tr>
<td>6.24</td>
<td>20%</td>
<td>51%</td>
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</table>
M/V Fishing Vessel ECO No. 2

More Efficient Belt & Alternator Savings, cont.

- 3 Alternators and Belts: (3% Belts; 7% Alternators)
- Amperages are Estimated

- Long Line Operational Profile:
  - A#1 ME: \(\frac{(12\text{v} \times 160\text{ amps})}{1000} \times 140\text{ hrs}) = 269\text{ kWh / yr}\)
  - A#1 ME: \(\frac{(12\text{v} \times 80\text{ amps})}{1000} \times 260\text{ hrs}) = 250\text{ kWh / yr}\)
  - A#2 ME: \(\frac{(24\text{v} \times 100\text{ amps})}{1000} \times 140\text{ hrs}) = 336\text{ kWh / yr}\)
  - A#2 ME: \(\frac{(24\text{v} \times 50\text{ amps})}{1000} \times 260\text{ hrs}) = 312\text{ kWh / yr}\)
  - A#3 Aux: \(\frac{(12\text{v} \times 90\text{ amps})}{1000} \times 40\text{ hrs}) = 43\text{ kWh / yr}\)

- \(1,210\text{ kWh} \times \$0.52/\text{kWh} = \$629\)

- \(\$629 \times 0.10 = \$63/\text{yr}\)

To Be Continued..................................
M/V Fishing Vessel ECO No. 3

- **Freezer Shore Power**
  - 7.5 Ton System ≈ 26.4 kWh ≈ 90,000 btuh *(Full Load)*
  - Operates Dockside 10 days /yr ........24 hrs/ day
  - Hydraulically Driven off Engines: ("Cold Hold Mode")
    - 4.21 in³/rev x 1200 revs/min = 21.9 gpm
    - Hp = (21.9 gpm x 1300 psi)/1714 (0.85) ~ 20hp
    - 20hp ~ 15 kW
    - 15 kW x 24hrs/day x 10 days = 3600 kWh / yr
  - **Freezer Shore Power Annual Savings:**
    - 3600 kWh x ($0.52/kWh - $0.11/kWh) = $1,476(*)

*We will see this $1,476 again…….*
ECO Financial Analysis

- "Bankers Approach to $'s" - Capital Loan
- It boils down to an ..... "Analysis of a Discounted Series of Cash Flows" ......
  - ECO's initial cost to Implement? (Investment)
  - Anticipated annual "net returns" from that ECO? (Annual Savings – Maintenance costs can be included)
  - What is your "cost of money"? (Discount Rate)
    • FO Cost Escalation and General Inflation factors
    • Risk, History, and Basic Time Value of Money
  - Time Frame?
ECO Financial Analysis, cont.

- From this Analysis, Metrics are weighed and compared to arrive at a business decision:
  
  - **ROI** – (Total) Return on Investment: (Simplest Form)
    
    • \( \frac{\text{Total negative cash flows} + \text{Total positive cash flows}}{|\text{Total negative cash flows}|} \)
  
  - **Pay Back Period:**
    
    • How long it takes for the fully implemented ECO's stream of discounted cash flows to turn positive. This is the break even point of the ECO (investment).
  
  - **NPV - Net Present Value:** The value or amount of money in today's dollars, that the total "net" ECO (investment) will result in, over the course of its life (analysis time frame)
ECO Financial Analysis, cont.

- These (3) Financial Metrics are weighed and compared against the alternative costs of making no changes (leaving the status quo), and other operational and business considerations, to arrive at an action decision.

- Financial Analysis Software for Cash Flow Analysis
  - [www.axia-consulting.co.uk](http://www.axia-consulting.co.uk) (Freeware)
  - Multiple Dozens of ROI / Discounted Cash Flow Freeware
  - Any $50 Business Calculator
ECO No. 3: Freezer Shore Power Cash Flows

Results Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Total project cost savings/income $'000</td>
<td>15.5</td>
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<tr>
<td>Total project expenditures $'000</td>
<td>-9.9</td>
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<tr>
<td>Net project savings / income $'000</td>
<td>5.6</td>
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<tr>
<td>ROI (return on investment - after 10 years)</td>
<td>57%</td>
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<td>NPV (net present value) $' 000 at a discount rate of:</td>
<td>2.5</td>
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<td>Payback year</td>
<td>Year 7</td>
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Years

1 2 3 4 5 6 7 8 9 10

$'000

Cash flow

Cumulative cash flow
ECO No. 3 Financial Analysis, cont.

ECO No. 3: Shore Power Mods
Annual Cost Savings Components

- Reduced Generator Maintenance: 5%
- Fuel Cost Savings: 95%

ECO No. 3: Shore Power Mods
Expenditure Components

- Purchase/Install 22gpm/1200 psi Hydraulic Pump: 10%
- Fab/Install Foundations & Piping Mods: 14%
- Contingency: 20%
- Vessel Electrical Wiring: 18%
- Purchase/Install 20hp Motor and Motor Controller: 33%
- Shore Power Cable & 50 Amp Receptacle: 4%
ECO No. 3 Financial Analysis, cont.

### ECO#3 Freezer Shore Power Cost Savings

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<tr>
<th>Year</th>
<th>$'000</th>
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<td>1.55</td>
<td>1.55</td>
<td>1.55</td>
<td>1.55</td>
<td>15.5</td>
</tr>
</tbody>
</table>

### ECO#3 Vessel Modification’s Expenditures

<table>
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<tr>
<th>Item Description</th>
<th>$'000</th>
<th>$'000</th>
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<tr>
<td>1.1 Fuel Cost Savings</td>
<td>0.43</td>
<td>0.4</td>
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<tr>
<td>1.2 Vessel Electrical Wiring</td>
<td>1.80</td>
<td>1.6</td>
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<tr>
<td>1.3 Purchase/Install 20hp Motor and Motor Controller</td>
<td>3.29</td>
<td>3.3</td>
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<tr>
<td>1.4 Purchase/Install 22gpm/1200 psi Hydraulic Pump</td>
<td>1.02</td>
<td>1.0</td>
</tr>
<tr>
<td>1.5 Fab/Install Foundations &amp; Piping Mods</td>
<td>1.39</td>
<td>1.4</td>
</tr>
<tr>
<td>1.6 Contingency</td>
<td>1.94</td>
<td>1.9</td>
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<td>Sub total expenditure</td>
<td>9.44</td>
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<tr>
<td>Cash flow</td>
<td>-3.44</td>
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<tr>
<td>Cumulative cash flow</td>
<td>-3.44</td>
<td>-7.89</td>
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</table>

### ECO#3 Project Discount Rate

- Cost of Money ("Opportunity Cost") | 2.5%
- Inflation (PC 4.0%, COL 1.0% @ 50% or 1.0% @ 50% or 1.0% @ 50%) | 2.5%
- Net discount rate | 2.5%
- Which is equivalent to a discount factor of | 0.95

### ECO#3 Discounted cash flow

- Discounted cash flow | -3.44 | -1.6 | 1.4 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 2.5%
- Cumulative discounted cash flow | -3.44 | -9.0 | -6.6 | -5.2 | -4.0 | -2.7 | -1.6 | -0.5 | 0.5 | 1.5 | 2.5%

### ECO#3 Project Assumptions

- A | All work is by Shipyard labor @ $60/Hr.
- B | Estimated Vessel Electrical costs = $0.52/kWh
- C | Estimated Shore Power costs = $0.11/kWh
- D | Annual Time at Dock is 10 days
- E | Freezer power consumption is estimated at 15kW, and is based on maintaining "cold holds" only. Not taking the holds down to freezer temps.
- F | Total Freezer Power Consumption, 15kW x 24 hrs./day x 10 days = 3600 kWh / yr
- G | Total Annual Savings = ((3600 kWh x $0.52/kWh) - (3600 kWh x $0.11/kWh)) = $1,476

**Elliott Bay Design Group**
Wrap Up – 7 Fundamental EA/EC Ideas

1) Measure and Monitor Fuel & Energy Consumption
   – Fuel Meters; Utility Bills; Fuel Logs; Amps/Voltages; Time

2) Apply Common Sense

3) Progress and Savings can be Incremental

4) Pick the Low Hanging Fruit
   – Operational Choices and Strategies
   – Clean Hull
   – Lights, Electric Motors, Air Compressors, Belts, Right Sizing Equipment

5) Study and Evaluate the High Fruit
   • Waste Heat Recovery
   • Optimize Propulsion and Power Generating / Conversion Equipment, and System Designs
   • Bulbous Bows and Other Hull / Appendage / Gear Improvements

6) Nothing is Free – Don't Take any Wooden Nickels

7) A Penny Saved = 3 Pennies Earned