Life Cycle Assessment of Renewable Energy Systems

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Overview

- Renewable energy and LCA
- Renewable energy life cycle
- Wave energy case study
- Technology comparisons

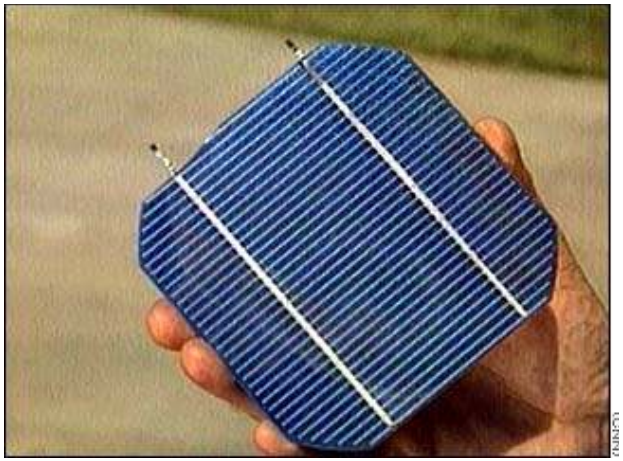
Renewable Energy and LCA

- Renewable energy sources are regarded as one of the solutions to the twin challenges of climate change and energy security
- Increasing interest in carbon footprint among companies and the general public
  - many renewable developers are asked for this information
- Persistent myth that renewable energy devices never pay back the energy or CO_2 embedded in them
  - particularly prevalent among anti-wind lobby
- Increasing number of technologies now assessed

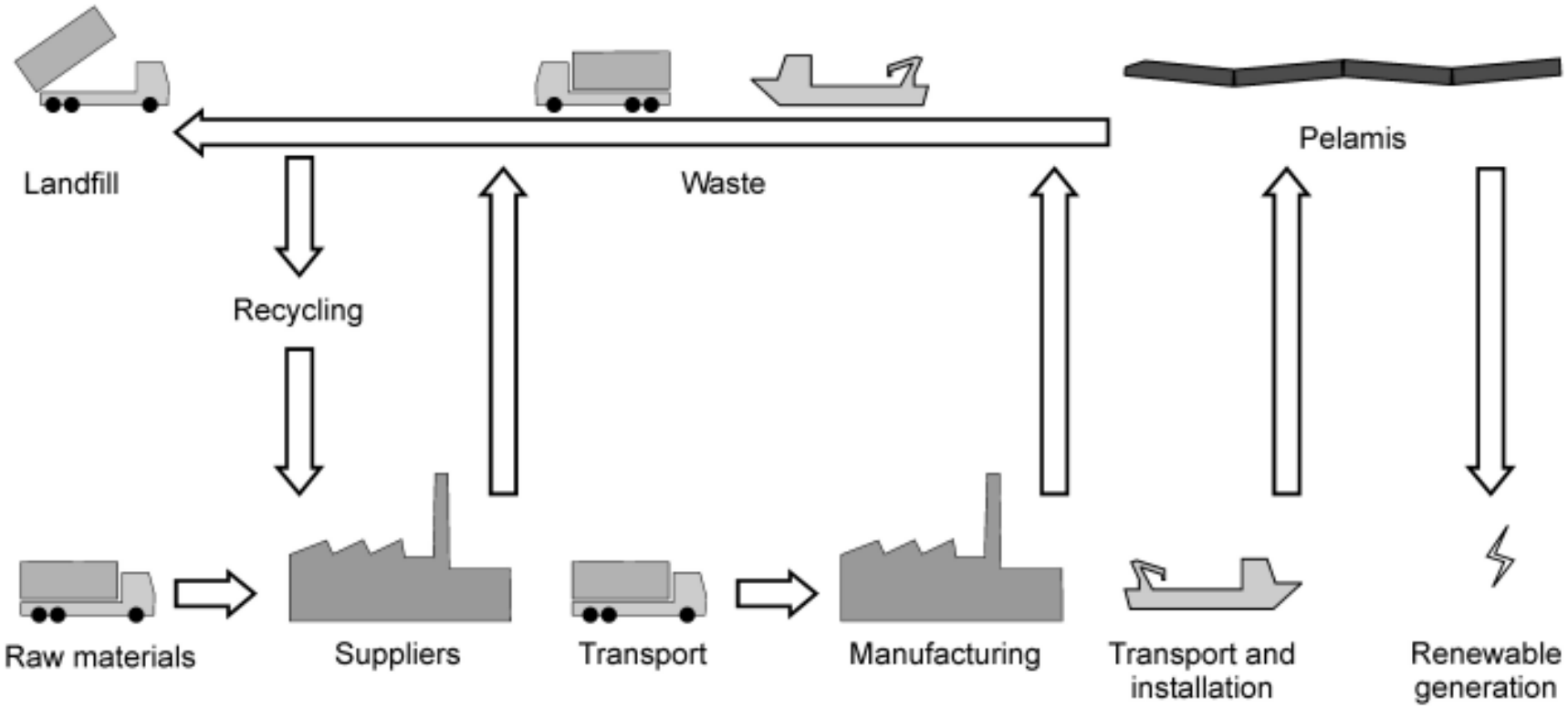
Renewable Energy and LCA

- Functional unit is kWh of electrical output
- Key indicators
  - Energy intensity (kJ/kWh)
  - Carbon intensity or footprint (gCO_2/kWh)
  - Energy payback (months)
  - Carbon payback (months)
  - Energy Return on Energy Invested (multiples)

Renewable Technologies

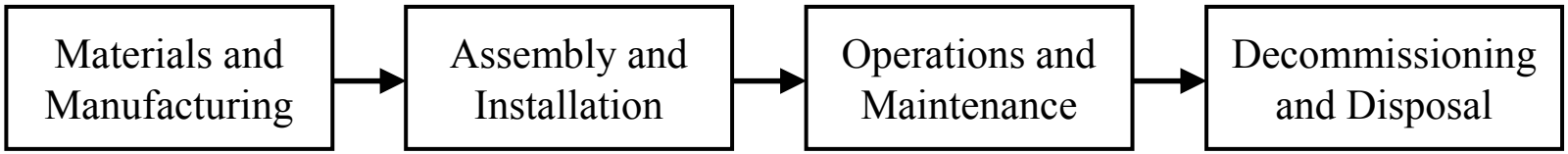


Renewable Energy Life Cycle



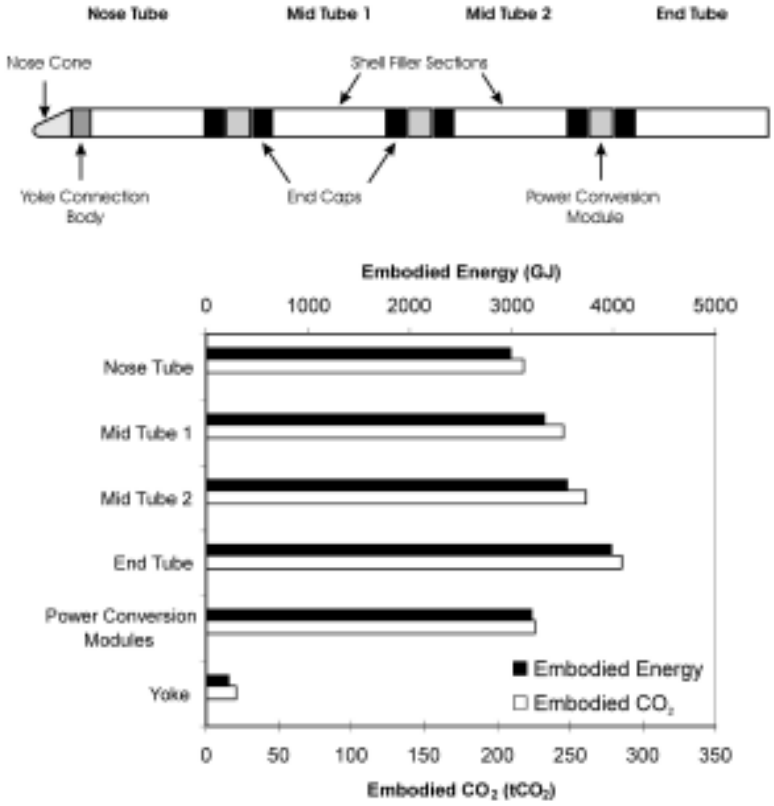
Wave Energy Case Study

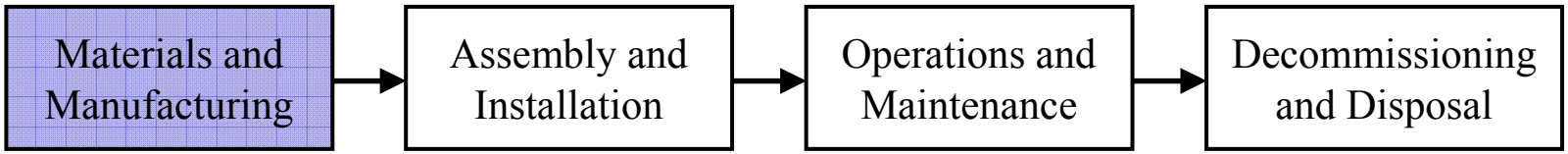
- Pelamis
  - Pelamis Wave Power Ltd, Edinburgh
  - 120 m long, 3.5m diameter
  - 750 kW capacity, designed for survival
  - designed to be laid out in farms
- Scope of assessment
  - 20 year life, single converter
- LCA datasets used
  - Bath's Inventory of Carbon and Energy and others (pref. ISO 14040)
- Life cycle stages examined



Materials and Manufacturing

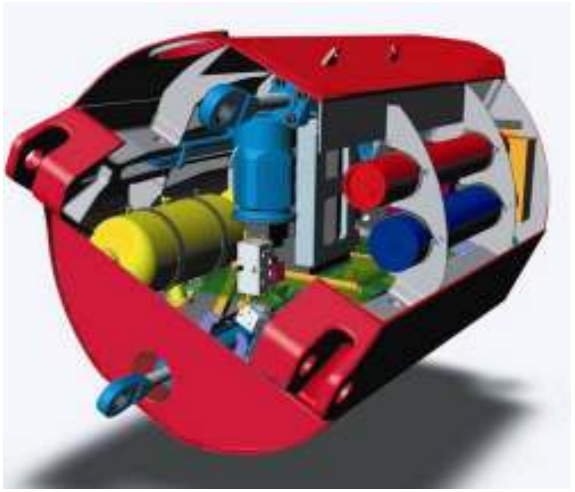
- Structure
  - several subcomponents
  - mostly steel plate
  - cut, welded, sand-blasted, painted
  - ballast (sand) to set buoyancy
- Materials account for 96% of embodied energy/CO_2 in structure

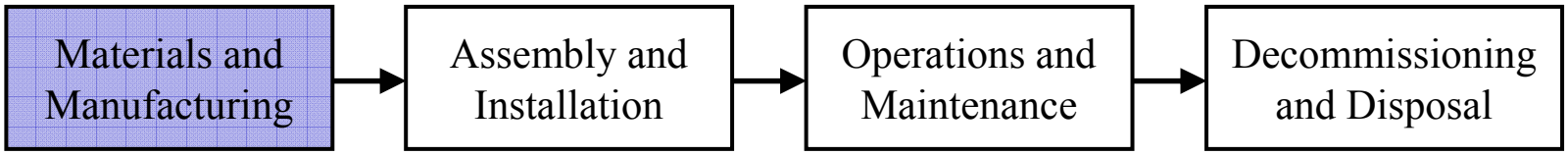




Materials and Manufacturing

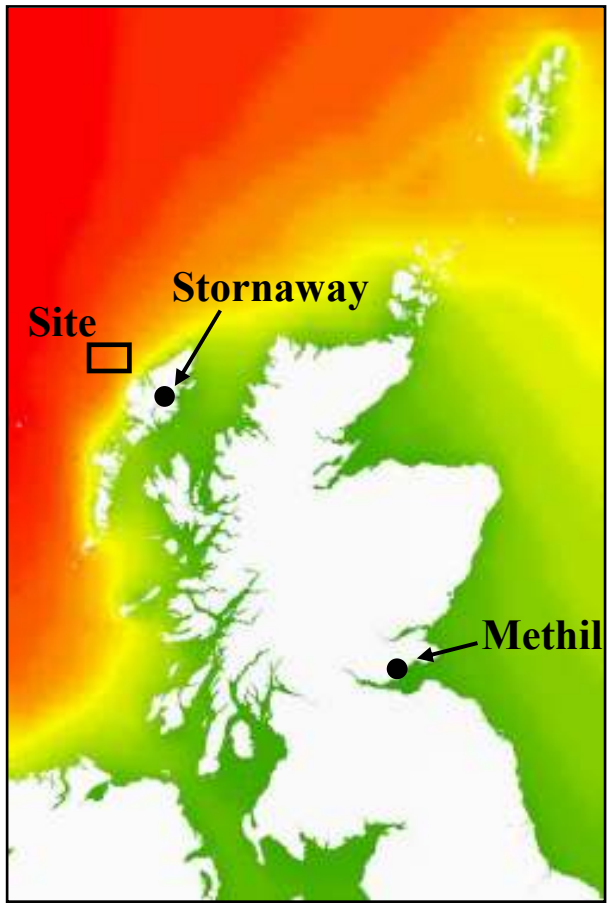
- Hydraulic systems
  - rams, accumulators, motors
  - mostly within power conversion module
- Electrical and electronics
  - mostly within power conversion module
  - in excess of 500 components
  - derived cost-energy/CO_2 relationships
- Moorings
  - anchors, chains, lines, release mechanism

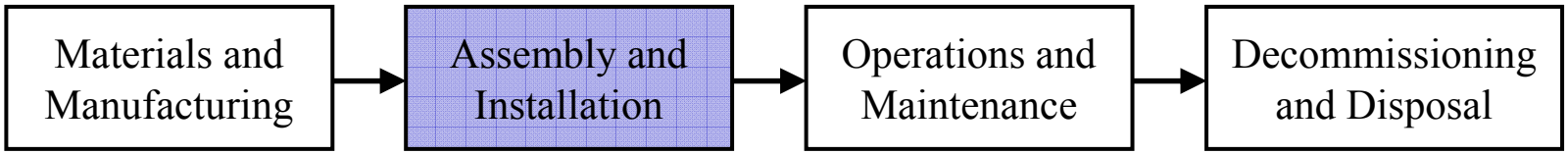




Assembly and Installation

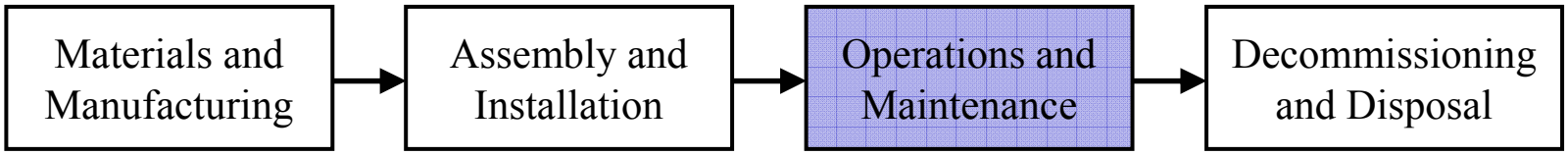
- Site off Western Isles (~55 kW)
- Device assembly
  - PCMs assembled at Methil
  - Structure manufactured near Stornaway
  - Components transported to port near site
- Installation
  - Moorings installation
  - Power cable installation
  - Sea trials
  - Tow and latching
- Inputs are mostly fuel related





Operations and Maintenance

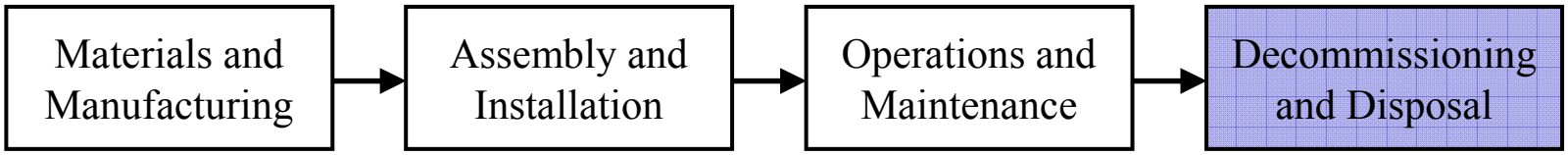
- Pelamis is remotely operated and controlled
  - System redundancy
  - Limited need for intervention
- Device inspection every 6 months
  - Towed to and from port using multicat vessel
- Moorings inspected every 2 months
  - Use of ROV and smaller boat
- Impacts again fuel derrived



Decommissioning and Disposal

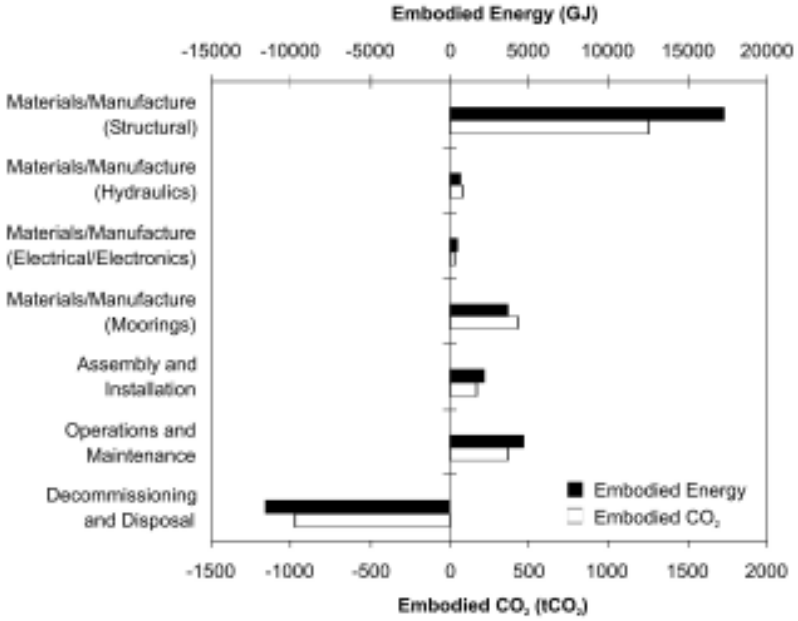
- Decommissioning
  - final detachment and towing
  - recovery of moorings

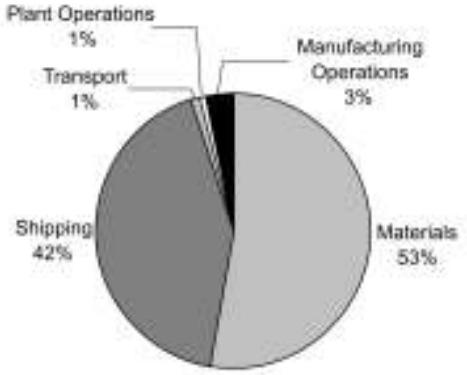
- Disassembly and recycling
  - credit based on avoided primary materials
  - standard method for metals
  - 90% recycling rate for metals
  - recovery of 500+ tonnes of steel



Life Cycle Summary

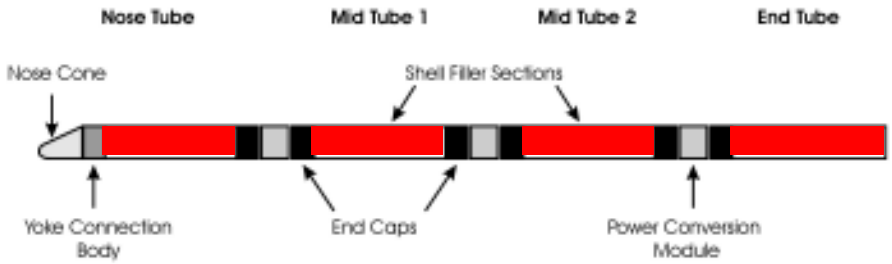
- Net life cycle emissions 1356 tCO_2
  - manufacture of structure most significant
- Recycling credit
  - ~26% energy and 28% CO_2
  - comparable with wind turbines
- Functional split revealing
  - shipping emissions significant
- Indicators
  - Energy intensity 293 kJ/kWh
  - Carbon intensity 23 gCO_2/kWh
  - Carbon payback 13 months

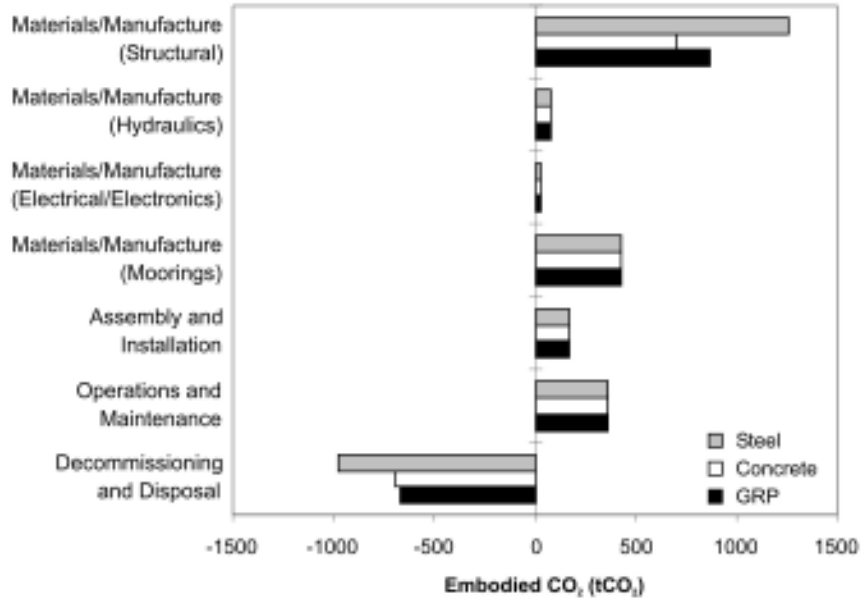




Evaluating Design Changes

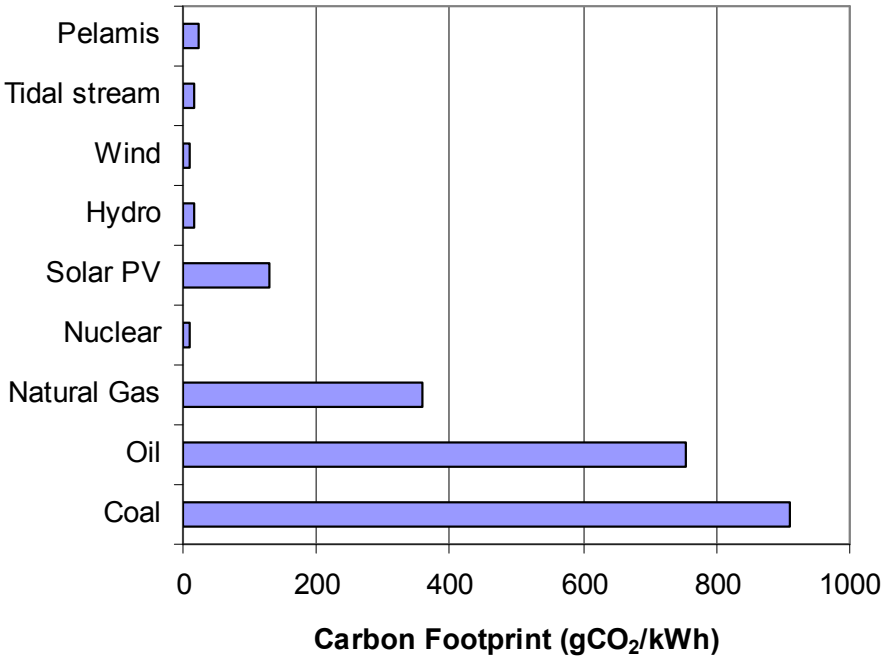
- Pelamis design evolving
  - opportunities to reduce cost and environmental impact
- Options to replace steel tubes with reinforced concrete or glass reinforced plastic (GRP)
- Footprint reduced by
  - 6% for GRP
  - 19% for concrete





Comparing Generating Technologies

- Renewables much less intensive than fossil generation
- Pelamis appears to be low carbon option
  - opportunities to reduce footprint
- Challenges in comparing technologies
  - international manufacturing
  - electricity network CO_2 intensity
  - stage of development



Conclusions

- Much interest in carbon footprint of renewable energy
- Most of the embodied energy and CO_2 derives from the manufacture of the renewable generator
- For marine technologies shipping may be significant factor
- Lots of challenges in comparing technologies
- Need for proper guidance on performing LCAs and comparisons (e.g. FP7 EquiMar)