Harnessing the power of the ocean currents

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recondoil.com/pros-cons-tidal-energy
Marine Renewable Energy

Wave & Wind Energy – Received the most attention

Wind Energy

Ocean & Tidal Currents

Photo by Ethan Andrews

https://wavetidalinfo.weebly.com
Why Tidal Energy? Tidal power is reliable!

→ Know how much electricity will be generated at given time

Water denser than air (~800x)

→ Tidal flow of a few m/s ≈ 450 km/h (300 mph) wind.

→ Tidal turbines smaller than wind turbines.

Tides: gravitational pull of moon and sun with the rotation of the earth
Tides – Minas Passage, Nova Scotia
Max tidal range 15m (50 ft)

Thomas Hill Standpipe

High Water

Low Water

Adapted from: Chris Brackley/Canadian Geographic
Tides – Minas Passage, Nova Scotia
Max tidal range 15m (50 ft)

Thomas Hill Standpipe

The Tides:
• 160 billion tons of water each tide in Bay of Fundy
• 14 billion tons through Minas Passage
• Flow 2-5 m/s (18 km/h)

Power Potential:
• 50,000 MW – Estimated energy in Bay of Fundy
• 6,000-8,000 MW – Estimated energy in Minas Passage
• 300 MW – Nova Scotia’s goal for power generation in Minas Passage
→ 270,000 HOMES! (only 1% of total potential!)
Tides around the world

Red – Large Tides
Blue – Small Tides

Adapted from: R. Ray, TOPEX/Poseidon: Revealing Hidden Tidal Energy GSFC, NASA.
How electricity is generated
Four prototypes in Minas Passage

Single-rotor turbine
On Seabed

Floating dual-rotor turbine
Moored to bottom

Semi-submerged Gravity base

Single-rotor turbine
On Seabed

1. PS2
   Company: OpenHydro
   Device: Open-centre single-rotor turbine on a subsea base
   Size: 16-metre-diameter rotor
   Production: 2 MW
   Deployment: Summer 2015

2. SEAGEN-F
   Company: Minas Energy-Marine Current Turbines-Bluewater
   Device: Floating dual-rotor turbine moored by cables
   Size: 40 metres long, 16-metre rotors
   Production: 2 MW
   Deployment: 2016 or 2017

3. TRITON
   Company: Black Rock Tidal Power
   Device: Semi-submerged, 36-40 turbine array on a gravity base
   Size: 46.6 metres long, 4-metre-diameter rotors
   Production: 2.5 MW
   Deployment: Fall 2016

4. AR1500
   Company: Atlantis-Lockheed Martin- Irving Shipbuilding
   Device: Single-rotor turbine on a subsea foundation
   Size: 18-metre-diameter rotor
   Production: 1.5 MW
   Deployment: 2017

Illustration: Tyana Awada/Canadian Geographic
What type of turbine?

- Estuary
- Floating platform – moored to seabed

<table>
<thead>
<tr>
<th>Parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform Width</td>
<td>6 m</td>
</tr>
<tr>
<td>Platform Length</td>
<td>8 m</td>
</tr>
<tr>
<td>Draft</td>
<td>0.3 m</td>
</tr>
</tbody>
</table>

![Diagram of floating platform](image_url)
Southwest Coast of France
Goals:

1. Determine the energy potential in the Gironde

2. Examine how implementing turbines will affect the environmental conditions of the estuary
   → Water levels
   → Currents
   → Sediment transport
Why the Gironde is Unique

- In an area of large tidal range, but also:
  - Coastline convergence — STRONG tidal currents
Why the Gironde is Unique

• In an area of large tidal range, but also:
  • Coastline convergence – STRONG tidal currents

Tidal Bore, France
http://www.theinertia.com/
Why the Gironde is Unique

• In an area of large tidal range, but also:
  • Coastline convergence – STRONG tidal currents

Steps:
1. Develop numerical model to simulate currents in the Gironde
   • Validate model

2. Determine optimal location for turbine placement
   • Energy potential
   • Feasibility

3. Determine optimal orientation of turbines

4. Analyze affects on environment.
Model

2 km to 20 m mesh size

Forced by Tide

River Discharge
Tidal Validation

9 tide stations

Amplification

Flood

Ebb

Time (days)

Bordeaux
rmse = 0.12

Pailliac
rmse = 0.11

Port Bloc
rmse = 0.08

Day of September 2009
Velocity Validation

Acoustic Doppler Current Profiler (ADCP)

www.teledynemarine.com

www.hydro-international.com
Velocity Validation

1. ADCP on mooring device
2. Put in water with huge winch
3. Let out rope attached to mooring in flood and ebb tide directions
4. Drop huge anchors to make sure it stays put for 6 months
5. Hope it is still there 6 months later...
Velocity Validation

Compare model results with data

After all that work we get…

![Graph showing velocity validation results with ADCP 1 and ADCP 2, and the Day of 2015 scale. RMSE values are 0.08 for ADCP 1 and 0.10 for ADCP 2.]
What is the best location for the turbines?

- Identify locations with highest energy potential
  
  \[ E = \sum_{t=T_0}^{t=T_f} \frac{1}{2} \rho U(t)^3 \Delta t \text{ [kWh m}^{-2} \text{ yr}^{-1}] \]

  - Le Verdon
  - Lamena
  - Roque de Thau
  - Isle St. Georges

- To consider:
  - Environmental feasibility for the turbines
  - Obstruction of navigation channel
  - Proximity to an electric grid

Kinetic energy power density

\(~12000 \text{ kWh/yr}\)
What is the best location for the turbines?

Turbines generate electricity ONLY when currents exceed this velocity!

<table>
<thead>
<tr>
<th>Place</th>
<th>% time vel &gt;1.4 m/s (surface)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roque de Thau</td>
<td>27.6%</td>
</tr>
<tr>
<td>Lamena</td>
<td>17.5%</td>
</tr>
<tr>
<td>Isle St. Georges</td>
<td>35.5%</td>
</tr>
<tr>
<td>Le Verdon</td>
<td>NOT considered due to environmental conditions</td>
</tr>
</tbody>
</table>

Conclusion: The turbines will be deployed at **Roque de Thau!!**
Where to put the turbines in the model?

Provided by Bertin Technologies
Implementation of the turbines in 3D.
Impact of the tidal turbines on the currents [m/s]

Strategic placement of turbines in a tidal estuary:
→ Reduce wake effects within the tidal array
→ Maximum energy captured from the system as a whole.
Turbines Inline Orientation
→ Wake affects, decrease energy extraction
Turbines Staggered Orientation

→ More energy potential, more environmental change
Considerations

• Effect of turbines on currents
  → change natural flow structure in the estuary, which will affect:
  • Sediments
    → this estuary has a lot of mud!
    → development of new morphological features
      → we don’t want any new underwater mountains created by the turbines
      → Dredge 24/7/365
Impact on Suspended Sediment Concentration (SSC)

Start with 4,000,000 tons of sediment near the rivers to initiate
Impact of turbines on sediments in the estuary [mg/l]

Difference in sediment concentration with and without turbines

Turbines Create more far-field effects than anticipated!

More sediment

Less sediment

Turbine location

Lambert III
What we know:

→ Climate change is an imminent threat!
  → Must turn toward more sustainable energy solutions!

→ Tidal turbines are a reliable and efficient means of generating electricity in coastal locations. With potential locally!

→ We need to better understand how implementing the turbines will affect the natural environment.

→ More prototype designs need to be developed, tested and modeled.
  → ASCC at UMaine
Acknowledgements:
Sohaib Alahmed &

Thank you!!!