Bridges in New England That Show Promise for Feasible Tidal Power Generation: A Protocol for Retrofitting Bridges

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Abstract

The Living Bridge (Figures 3a and 3b) between Portsmouth, NH and Kittery, ME is an innovative and unique transportation marvel. It is the only gussetless vehicular truss bridge in the United States. It includes 40 sensors to monitor structural health and the neighboring estuarine ecosystem. Additionally, the Living Bridge includes a tidal turbine to convert tidal energy to electricity. During this project, 40 tidal bridges in New England were investigated for installation of the tidal turbine. A protocol was created to determine bridges that show promise for producing tidal power, like the Living Bridge. In conclusion, seven bridges were identified to show promise for feasibly producing electricity and suggestions were presented for future work.

Introduction

Tidal power (tidal energy) is a renewable energy source that uses tidal currents to generate power. To harness this energy, a turbine is installed in a river or stream to extract the kinetic energy from the flowing water and convert it into electrical energy. Depending on the power density (amount of power per volume of water) and the depth of the water, engineers choose appropriate turbines that can have the following variations:

- blade arrangement and orientation
- number of rotors
- rotor diameter
- rotor length
- turbine position relative to the area

The turbine chosen and deployed at the Living Bridge is a crossflow vertical axis turbine (Figures 1 and 2) with a 3 meter by 2 meter rotor. It has the ability to produce an average of 2 kW of power.

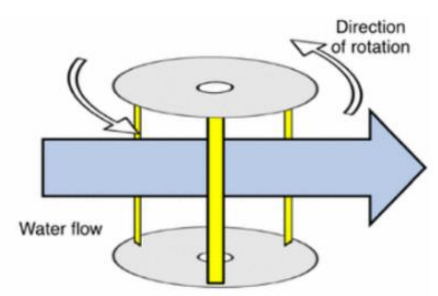


Figure 1: Crossflow Turbine


Figure 2: The Living Bridge Turbine

Figures 3a and 3b: The Location of the Turbine on the Living Bridge

Since using tidal power is a relatively new renewable energy source option, there are many benefits and drawbacks when considering installing a tidal turbine (Table 1).

Table 1: Comparison of Benefits and Drawbacks of Tidal Energy

Benefits	Drawbacks
no fuel costs (i.e., oil)	can be expensive to send power from underwater turbine to the grid
clean energy	salt water corrosion
no waste products (i.e., uranium rods)	biofouling
less expensive to operate compared with other renewable energy plants	start up costs can be higher than other power plants
predictable source of kinetic energy (tides are predictable)	can be difficult to find suitable site with adequate current
minimal noise pollution	can impact ecosystem

Methods

1. Formulated objective: Which bridges in New England show promise for feasible tidal power generation?
2. Collected data about tidal current speeds at 40 bridges in New England (Figure 4) and calculated the average power density (Figure 5)
3. Created a protocol based on bridge constraints, power density, environmental conditions, and human interest (Table 2)
4. Applied protocol to bridges

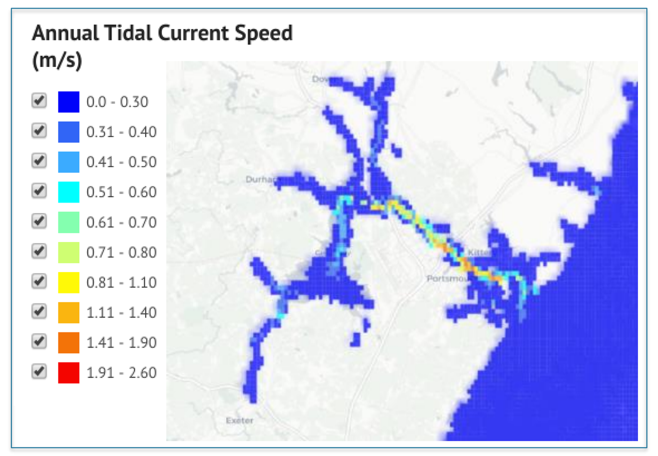


Figure 4: MHK Atlas Map

$$P_{\mathrm{d}} = \frac{P}{A} = \frac{1}{2}\rho C_{\mathrm{p}} u_{\infty}^{3}$$

Figure 5: Power Density Equation

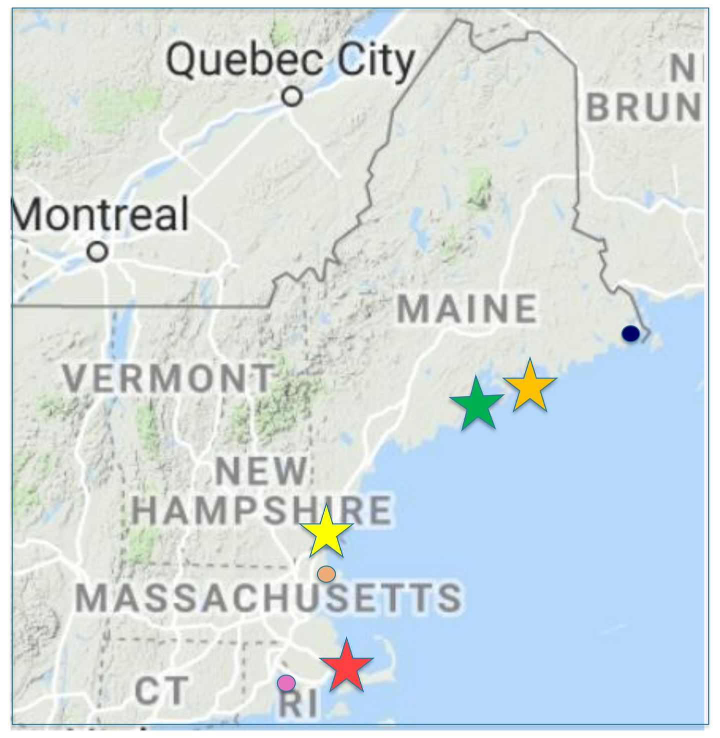


Figure 6: Tidal Bridges in New England

Table 2: Protocol

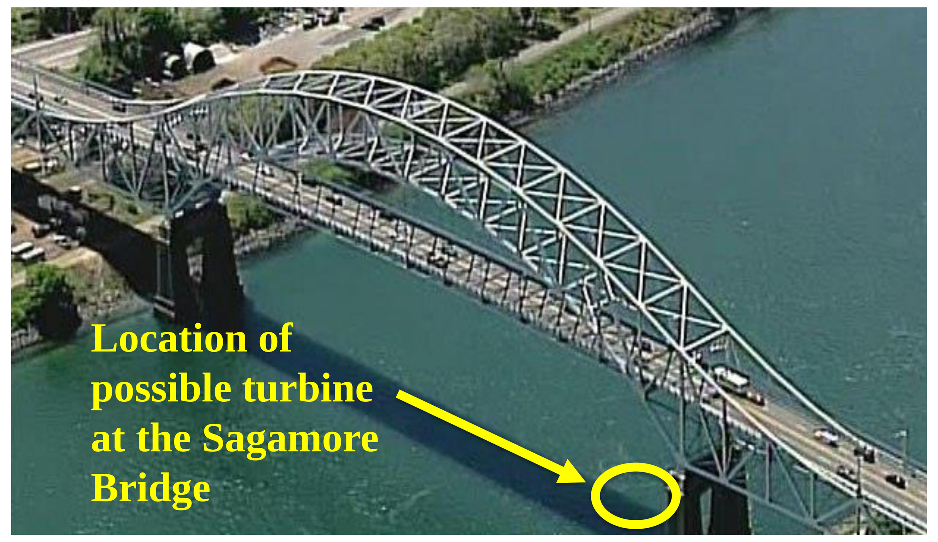
Power Density	• Could the tidal current support a turbine?
Adaptability to Constraints	• Is the distance from the mean lower low tide to the seabed sufficient? • Is the distance from pier to pier sufficient?
Access to Turbine	• Can engineers maintain the turbine easily? • Is the distance from the mean higher high tide to bridge sufficient?
Potential for Energy Usage	• Is there a need for bridge scale energy (i.e., emergency lighting, sensors, aesthetic lighting)? • Is there a need for utility scale energy in the surrounding area?
Environmental Impacts	• Could the turbine negatively affect the natural ecosystem? • Could the turbine negatively affect human recreation and/or businesses?
Community Interest and Engagement	• Can the turbine add value to the community? • Is there local and/or political appreciation and support?
Expected Lifespan of the Bridge	• Is the bridge currently in need of renovations, remodeling, or replacement?
Funding	• Is there capital to fund and maintain the turbine? • Is there an opportunity for power company contributions?

Results

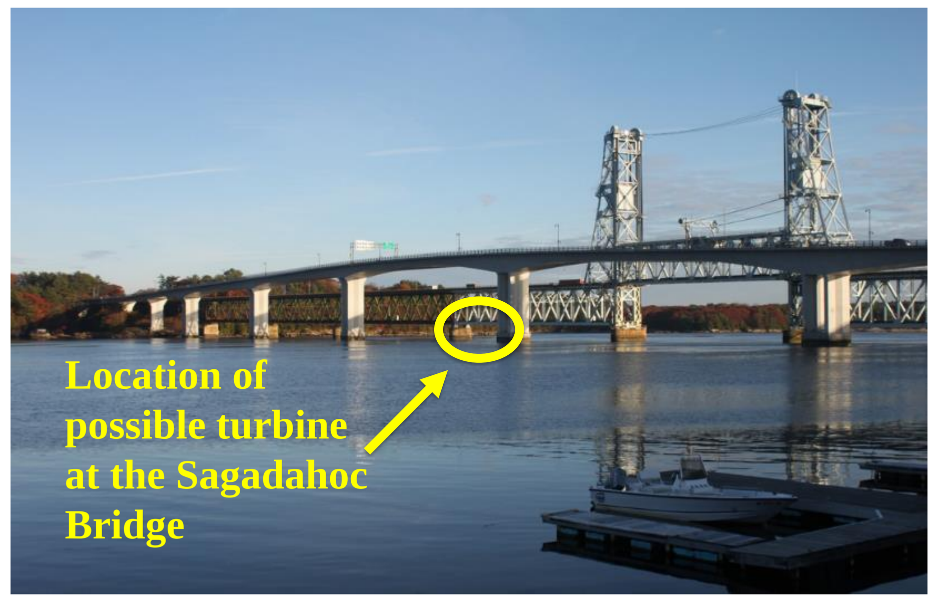
Based on the protocol, 7 out of the 40 bridges studied showed promise for tidal power generation. Three examples are listed below, ranked from most feasible to least:

The **Deer Isle – Sedgwick Bridge**, over the Eggemoggin Reach, has the fastest current in New England besides the Piscataqua River (the Living Bridge). It has a power density of 1025.2 W/m2 (at 100% efficiency). At this bridge, the water is deep enough (75 feet), and there is access to a potential turbine (98 feet from platform to bridge).

The **Sagamore Bridge** over the Cape Cod Canal has a power density is 225 W/m2 (at 100% efficiency), there is access to a turbine (135 feet from platform to bridge), and there is a need for a lighting system on the bridge. However, although the water depth in the Canal is about 35 feet, it may be too shallow to install a turbine since the piers are located near the banks.



The **Sagadahoc Bridge** over the Kennebec River has high community value with its bike lanes and wide pedestrian sidewalks. The clearance from platform to bridge is 75 feet. However, it has a lower power density (91 W/m2 at 100% efficiency) than the bridges listed above and would need to a smaller turbine.



Future Work

- Creating an interactive website with a searchable database for engineers and bridge programmers
- Investigating other tidal areas in the United States (i.e., Cook Inlet in Alaska, Strait of Georgia in Washington, San Francisco Bay in California) for feasible locations for tidal power

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