THE HYDROELECTRIC CANAL

GENERATING RESILIENT URBAN ECOLOGIES

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Abstract

We propose to harness clean energy through hydropower generation from tidal changes and storm surges in low-lying urban areas, as a means of shaping economically and environmentally resilient, self-sustaining communities. Our proposal offers an array of integrated landscaping, ecological restoration, urban development and financing strategies for achieving this goal. The latter include public-private partnerships for creating a new energy-producing, amenity-laden infrastructure that reduces risk to communities and investors.
Introduction

Executive Summary

Historical Background:

Our proposal draws from a hydropower generation method from the 1640s: Boston's Mill Creek connected a northern tidal basin (Mill Pond) with the southern harbor (Town Cove), harnessing tidal changes to power strategically located gristmills at the creek's ends. This historic fusion of landscape and infrastructure energized Boston's new economy and community.

Core Concept:

Some 400 years later, we propose cutting a channel through Columbia Point to connect the northern Old Harbor with the southern Savin Hill Cove. The new Morrissey Channel would capture rising sea levels and tidal changes and embrace the ebb and flow of natural water currents to generate hydroelectric energy through advanced turbine technologies, which would power communities and build lively public spaces. This ecologically sustainable urban model would assume a new form of resilient urbanism that generates an amenity-rich landscape, restored ecology, and an economically viable, self-sustaining community.

Design Process:

We assembled a team of landscape architects, ecologists, engineers, venture capitalists, economists, cost estimators, and leading entrepreneurs and scientists advancing turbine technologies for river and ocean applications. Our three months of iterative design exploration included identification of market-ready turbines amenable to Columbia Point's ecology and landscape.

Submitting Team:

Paul Lukez Architecture & TEAM
Somerville, Massachusetts (Architecture & Urban Design)

Principal Team Members:
- Arup, New York, N.Y. (Engineering)
- Barnraisers Group LLC, Ayer, Massachusetts (Business Strategists - Financial Analysts - Consultants)
- C2 Studio Landscape Architecture, Fort Collins, Colorado
- Prof. Anamarija Frankic, University of Massachusetts Boston (Ecologist)
- Simpson Gumpertz & Heger Inc. (SGH), Waltham, Massachusetts (Structural Engineering)

Turbine Company Partners/Consultants: (put in order of importance/contribution)
- Blue Energy, Richmond, British Columbia, Canada
- MJ2 Technologies, La Cavalerie, France
- Natel Energy, Alameda, California
- OpenHydro, Dublin, Ireland
- Tidal Energy PTY Ltd., Brisbane, Australia
- Verdant Power, Inc., New York, N.Y.
- Whitestone Power Communications, Delta Junction, Alaska

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Research Results:

1. Turbines/Energy:

- Hydroelectric turbine makers determined that the most operable system for Morrissey Channel would be a tidal barrage, or a reservoir bordered by a turbine-studded dam. This system stores massive potential energy and converts it to mechanical energy as it is released across the turbines. VLH turbines by MJ2 Technologies or SLH100 turbines by Natel Energy can be adapted to this system, which can power between 1,000 and 2,000 homes at peak performance. (See appendix.)
- Storm surges and tidal waves can create additional energy through OpenHydro's Open Center Turbine or similar models.

2. Development Process and Finance:

- Our strategy can fully finance the estimated $1 billion or more required to build the channel, bridges, primary public spaces and resiliency strategies. We propose a public-private partnership model of development and risk-financing to shift the project costs and rewards burden from taxpayer to private sector.
- After 30-50 years, cash flows from excess energy will exceed the project's debt service costs, and will subsequently support a solid business model that could repay investors and fund future resilient infrastructures and landscapes.

3. Landscape/Ecology:

- This proposal would restore 232 hectares of intertidal salt marshes to store 4 million liters of water/acre, reduce tidal wave heights by 90% within 20 meters of the marsh edge, accrete sediment by 0.25 cm/m²/year, and absorb 481 tons of CO_2/year.
- It would also restore 63 acres of oyster/mussel/clam beds as a shoreline buffer filtering 30-50 gallons of water/day/oyster for water quality improvement and sediment reduction.
- Other ecological benefits would include shoreline revegetation for coastal habitats, biodiversity and landscape quality, intertidal pool expansion for rocky habitats, wetland remediation, and courtyard water recycling for stormwater management.

Additional Innovative Concepts:

1. Public-private partnerships would design, construct and manage the hydroelectric channel and its adjoining spaces. Private sources would fully fund this investment. The risk to investors is attractive, since the community will be resilient to rising sea levels, and its hydropower, solar, wind and geothermal systems will generate income streams for decades.
2. Private developers would design, build and manage Living Building Quads (LBQ) comprising multi-use buildings and courtyards, designed to meet Living Building Challenge (LBC) energy-performance, water- and waste-management and material design standards. These self-sufficient buildings would reduce the financial burdens of municipal water supply and sewage treatment.
3. To buffer low-lying areas against storm surges, hybrid landform dike-buildings would create a protective seawall, providing recreational opportunities and new coastal habitats for shellfish and marine animals.
4. Floating structures would be tethered to dike-buildings and boardwalks to adapt to rising sea levels.
5. To mitigate sediment deposit at the Neponset River mouth, the river will be rerouted to empty into Quincy Bay and Marina Bay's east side, restoring vitality to the flagging Squantum Marshes.
6. The Morrissey Channel would yield a continuous array of terraced bioremediation wetlands purifying and releasing wastewater into a 'captured' salt marsh. This would exchange salt water with the channel at a carefully calibrated rate via engineered channel-wall culverts.
7. UMass-Boston's erratically evolved campus would be integrated with a central green, a cohesive network of spaces and amenities, and redefinition of edges as symbolic campus gateways and useful back yards. A new network of streets, paths and bridges, multiple pedestrian and vehicular entries to Columbia Point, and a new train station with multimodal transit options near the John F. Kennedy Presidential Library and Museum would improve access to Columbia Point and UMass-Boston from Morrissey Boulevard, the Red Line and the Commuter Rail.

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Detailed Description of Primary Concepts and Features

Hydropower Concepts

Key Results / Concepts

At its core, this proposal identifies ways to develop hydropower generation systems as progenitors of resilient, self-sustaining communities. Here are our preliminary recommendations based on research and consultations with industry experts.
Our strategy calls for tidal turbines in a free-flowing, unrestricted channel. For this purpose, hydroelectric turbine manufacturers recommend a tidal barrage, or a reservoir bounded by a turbine-studded dam that can be gate-sealed to yield a height difference (hydraulic head) between the ocean and the captured water. This stores ample potential energy and converts it to mechanical energy as it is released across the turbines. For this purpose we selected the VLH Turbine by MJ2 Technologies of France (see Appendix).

Findings and Observations:

At peak flow and efficiency, the VLH could power 1,000-2,000 homes in the Morrissey Channel. Other turbine systems suitable for higher flow and deeper waters include Verdant Power's Kinetic Hydropower System, used in New York's East River, and Ocean Renewable Power Company's TideGEN system, powering Maine homes. The depths and speeds necessary to drive these turbines can be found in Massachusetts' Cape Cod Canal and Nantucket Sound, where water depths are at least 9 meters and currents can exceed 3 meters / sec.

Hydrology / Arup Associates

To justify our assumptions about the Morrissey Channel's energy generation capacity, we asked Arup Associates to research the site's hydrology and potential for generating energy using CFD modeling:

Computational fluid dynamics (CFD) modeling of Dorchester Bay was used to estimate indicative current and tidal stream flows around Columbia Point and through the proposed Morrissey Channel. The computational domain, developed from admiralty charts of Boston Harbor, was bounded on the west by Columbia Point and Savin Hill, the north by Old Harbor and Pleasure Bay, and the south by Squantum Point and Moon Head (Fig. 1). The domain's east extent stretches from Moon Head in the south through Thompson Island to Pleasure Bay in the north at a 20-degree angle west of north, selected to coincide with tidal stream measurements north of Thompson Island.

This approach allowed the harbor surface elevation's change rate at peak periods during flood and ebb to be input as a velocity boundary while accounting for inflow from or outflow to open ocean. The harbor surface height's change rate was derived from the first derivative of an idealized sinusoidal model of tidal changes (Fig. 2). The maximum and minimum rate changes were assigned as the harbor surface boundary conditions for maximum flood and ebb conditions, respectively. This assigned flow rate was the driving force for the predicted current flows through the Dorchester Bay model. Models were undertaken both with and without the proposed channel through Columbia Point. The model predictions of the current day harbor profile at both flood and ebb (Fig. 3) were qualitatively and semi-quantitatively compared to available current and tidal stream measurements, and were found to be in good agreement.

Conclusion:

These rates of flow are sufficient to power the proposed VHL turbines or other low head turbines, which typically require a velocity of 2-5 meters/second.

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Ecology / A. Frankic:
Prof. Anamarija Frankic, a local ecologist, contributed key insights and design input:

Living with water requires resilient integration of natural and human-built environments among watersheds, estuaries, urban harbors, and intertidal and subtidal coastal areas. Our innovative design reconnects and reuses fresh and marine water systems through restored fringing salt marshes, shellfish beds (including oyster reefs), tidal flats and pools, and eel-grass beds. Each of these natural habitats is integrated with human ones (e.g. Living Building Quads), providing comprehensive human and ecological services: primary production, food production, fish and shellfish habitat provision, biogeochemical cycling of nutrients, carbon sequestration, sediment trapping, wave attenuation, shoreline stabilization, water quality improvement, etc.

Landscape Design / C2

Landscape-ecology integration is key in this proposal. Jane Choi and Scott Carman of C2 Studio worked closely with our team on that.

To support a hydroelectric channel, the proposed landscape provides coastal resistance against sea-level rise for Columbia Point and creates maximal energy generation conditions. Landscape design could best address these existing conditions:

- excessive sediment deposit at the Neponset River mouth, which would hinder hydropower generation and limit Quincy Bay's navigability;
- vulnerability of low-lying areas to ever-increasing storm surges; and
- a combined sewer outfall (CSO) in Patten's Cove that discharges untreated wastewater into the bay, devastating marine habitats and limiting human recreation possibilities.

Our innovative landscape strategies would integrate human and natural systems while supporting energy generation. To reduce sedimentation, the Neponset would be rerouted to empty into Quincy Bay and Marina Bay's east side, restoring vitality to the flagging Squantum Marshes. Hybrid dike-buildings would create a protective wall to buffer storm surge, give marine animals new coastal habitats, and provide recreational opportunities.

The channel would create an 'urban floodplain' providing the public with a beneficial civic experience, a signature aesthetic and storm/wastewater treatment. The continuous array of terraced bioremediation wetlands purify and release water into a 'captured' salt marsh, which exchanges salt water with the channel via engineered channel-wall culverts. This system extends to Patten's Cove, providing a final cleansing of treated water for release into the bay, while creating an ecological habitat maximizing coastal resilience and human enjoyment.

Finance and Building Process / BarnRaisers LLC and PM&C

This proposal is based on a financially viable development and financing model proposed by our economists, cost estimators and venture capitalists.

We propose a self-sustaining, privately financed development model:

1. A public-private entity will design, develop, fund and operate the hydroelectric channel and its adjacent lands.
2. Financing is sought from private-sector investors attracted to low-risk, long-term investments with strong future returns. Cash flows generated solely by hydropower-generated energy could finance the project's debt and operating costs for the first 50 years and yield returns of up to $250 million (NPV) in year 100. Profits generated after investment recuperation fund the community's resilient infrastructure and public amenities.
3. Living Building Quad (LBQ) development is phased over time (see text on LBQ). Each quad's development rights are sold to eligible developers, who must follow LBQ standards. These standards require 105% energy-independent and self-sustaining systems, thus reducing burdens on existing utilities and infrastructure.

Economic benefits include:

A. Financial risk to private investors is reduced.
B. Development opportunities and higher returns are attractive to developers, given the development's resilient, safe, amenity-rich environment.
C. Public investment and burdens on public utilities are reduced.
D. This economically and ecologically self-sustaining model offers an enhanced quality of place.

Living Building Quad Concept

Using the Living Building Challenge (LBC) as a guide, this proposal calls for Living Building Quads (LBQ), 4-to-6-story mixed-use building clusters around naturally landscaped courtyards serving as retention ponds for storm surges. All quads must meet LBC standards for energy performance, water and waste management, and material design so each quad will be self-sustaining. This would enable developers, owners and tenants to reduce long-term risk to rising sea levels while benefiting from lower energy costs and operating expenses. Since 105% of each block's energy needs must be met by on-site sources (see diagrams), extra energy (and monies) the hydro-channel generates will finance it and its public spaces, as well as future resilient infrastructure systems and public amenities.

Hybrid Landform Buildings

Flood maps show Columbia Point's susceptibility to rising tides and storm surges. Consequently, its inhabited areas—Harbor Point Apartments and Morrissey Boulevard's corridor—must be protected from rising water levels. In lieu of a seawall, a hybrid landform/building will be more effectively integrated into Columbia Point's evolving urban landscape. This building is part dike (landform) and part inhabitable structure (see diagrams), which seamlessly fuses the buildings and their uses into the community fabric and water edges.

Floating Architecture

One- and two-story structures would be tethered to the hybrid buildings and their boardwalks. The modularity of these buoyant buildings would adapt them to rising sea levels. They would also offer a prototype for expanding Columbia Point's footprint within the natural limits of the district's ecologies and systems.

Campus Plan

To give University of Massachusetts Boston's erratically developed campus of megastructures more coherence and integrity, we propose:

- a central campus green;
- a strong network of public spaces and amenities;
- a recrafted south edge as a symbolic university gateway and useful back yard;
- redefined exterior edges and common gathering areas as distinctive visual identities.

We also conceived a network of streets and paths that link UMass-Boston to local landmarks such as the Kennedy Library, Columbia Point's existing streets, the JFK/UMass MBTA station, and Morrissey Boulevard.

Bridges / Paul Kassabian

Two suspension bridges—one vehicular, one bike/pedestrian—would connect UMass-Boston directly to Morrissey Boulevard as an iconic gateway to the campus and Columbia Point. The cable-stayed design of the bridges enables their decks to be built simultaneously with their cable placements, thereby shortening their construction schedules.

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Transportation

Strategies to facilitate transit access to the Harbor Point Apartments, UMass-Boston and the Kennedy Library include:

- Multiple pedestrian and vehicular entry points into Columbia Point's east side;
- A Red Line extension incorporating a new harborside station near the Kennedy Library with multimodal transportation options including a new ferry;
- A bike/pedestrian path network with bike storage facilities;
- Integration of the JFK/UMass Red Line/Commuter Rail station into all of the above.

See appendix for detailed description of the process and resulting research / content.