Personal Hydroelectric Generator
Team 7

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Presentation Overview

- Problem statement
- Project scope
- Goal statement
- Competitive research
- Flow characteristics
- Constraints
- HOQ
- Turbine assessment and selection
- Alternator & battery assessment and selection
- Anchoring assessment and selection
- Conceptual Design
- Potential challenges
- Plans for Progress

Problem Scope

- Electricity is needed for present-day civilized life
- There is a growing interest in clean and renewable energy
    - Climate change and global warming
    - Smog and air pollution in large industrial centers
- Many locations are far from an electrical power grid
    - Campsites and Underdeveloped communities

Needs Statement & Goal Statement

- Need Statement:

  "People in remote locations do not have access to electricity for powering their electrical devices."

- Goal Statement:

  "Develop a portable device that transforms organic kinetic energy into usable electricity."

Objectives

- Produce 1kW from a flowing water source
- Minimize weight to ensure portability
- Environmentally friendly
- Easy to set up and user friendly

Generator Competition

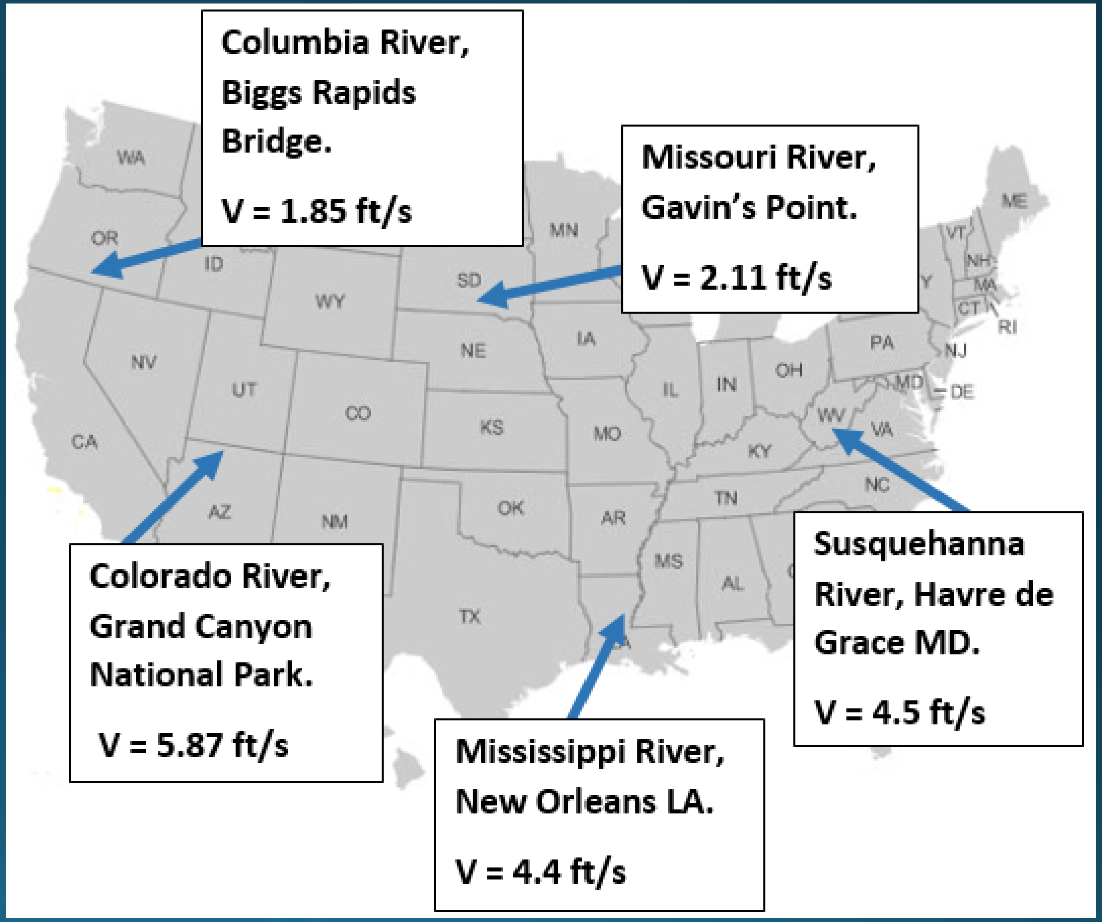
~1kW gas generators in today's market:

	PowerStroke[1] 1,100-Watt Gasoline Powered Portable Generator Model # PS901200	PowerBoss[2] 1,150-Watt Gasoline Powered Portable Generator with Briggs & Stratton Engine Model # 30627	Champion Power Equipment[3] 1,200/1,500-Watt Recoil Start Gasoline Powered Portable Generator Model # 42436	All Power[4] 1,200-Watt 2 Stroke Gasoline Powered Portable Generator Model # APG3004D	Average
Continuous Wattage (W)	1100	1150	1200	1000	**1112.50**
Full load fuel consumption (gallons/hour)	.29	0.71	.29	0.14	**0.36**
Operational volume (dB)	75.90	-	65	65	**68.63**
Product Weight (lb.)	55	60	61.70	46.20	**55.73**
Voltage (volts)	120	120	120	120	**120**
Price ($)	199.00	228.18	201.88	149.99	**194.76**

River Flow Characteristics

The velocity used for all calculations concerning our design will be based off the average of these 5 velocities located in different geological coordinates around our initial target market.

V = 3.75ft/s



Sources: Reference 5, 6, & 7

Project Constraints

- Device weight must not exceed 70lbs
- Compact (less than 3 ft^3)
- Unidirectional flow
- Water proof
- Corrosion resistant
- Durable
- Operates under 50 dBa (moderate level of sound)
- Complies with all safety codes

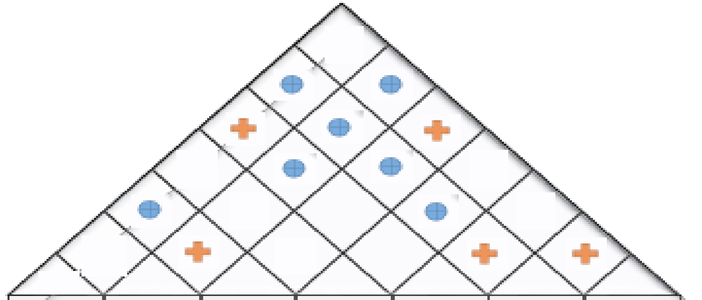
House of Quality

HOQ Legend

- 1-5 scale (5 best)

- 1-10 scale (10 direct correlation)

- Strong correlation
- Weak correlation



Engineering Characteristics →		Rate of Power Generation	Cost	Weight of Device	Stream Lined Profile	Power Output Efficiency	Mechanical Complexity	User Friendly	Selling Points
Customer requirements	Importance to Customer								
Functionality	5	10	5	2	9	10	5	4	225
Easy to Operate	3						6	10	64
Light Weight	4	7	7	10	4		3	8	117
Compact	4	6	2	8	6	2	6	8	114
Price	2	4	10	5		6	8	3	144
Durability	3		7	3	1	5	6	2	120
Aesthetically pleasing	1		4		8				48
Maintenance	3		3	5	2		5	8	92
Importance Weighting		110	115	116	102	85	128	150	

Competitor Comparison	Rate of Power Generation	Cost	Weight of Device	Stream Lined Profile	Power Output Efficiency	Mechanical Complexity	User Friendly
Direction of Improvement	+	-	-	+	+	-	+
HydroBee	40 W	$200	1 lb	Moderate	70%	Moderate	Very
Bourne Energy	500 W	$3,000	30 lbs	Not	70%	Very	Difficult
Target Values	500 W	$2,000	25lbs	Moderate	70%	Moderate	Moderate

House of Quality

After defining the relationships between the Customer Requirements and Engineering Characteristics, the most critical aspects of design were determined to be:

- Functionality
- Price
- Durability

Turbine Types

Image Source: Reference 8

Pelton and Turgo Turbines

- Rotational movement due to jetted flow into buckets of the runner
- Creates rotational energy from kinetic energy of water through impulse force
- Fin design gives strong support for high impact
- Efficiency as high as 90% under optimum working conditions

- Also rotational movement due to jetted flow, but half of the Pelton bucket design used
- Same power output as Pelton if the diameter is doubled
- Can handle higher flow rate than Pelton, but with lower efficiency
- Weaker fins because of vane construction

Sources: Reference 9 & 10

Pelton and Turgo Turbines

Analysis Related to Project Application

Pelton Turbine

- **Pros**:
  - Strong fin structure for high reliability
  - High efficiency rating
- **Cons**:
  - Very specific direction and angle of jetted flow needed

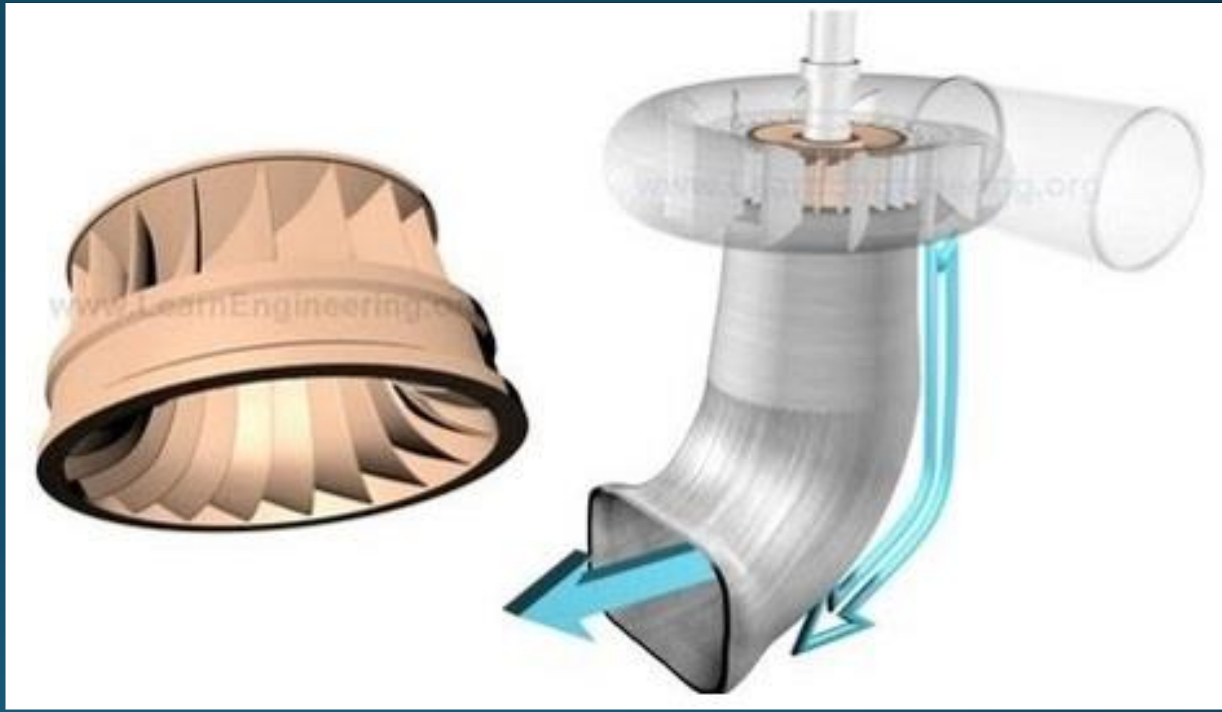
Turgo Turbine

- **Pros**:
  - More compact design than Pelton Turbine with same power output
  - Ability to handle very high flow rates
- **Cons**:
  - Weak fin construction is not suitable for application
  - Very specific direction and angle of jetted flow needed

Sources: Reference 9 & 10

Francis Turbines

- Francis Turbines are characterized as a Reaction turbine. These are the most common turbines used in hydroelectric generation.
- Encased within a spiral enclose
- Water is directed to the runners by guide vanes
- Operates under a water head of at least 45 meters.
- Efficiency as high as 90% under optimum working conditions



Sources: Reference 11 & 12

Francis Turbines

Analysis Related to Project Application

Francis Turbine

- **Pros**:
  - Tube shaped design helps decelerate exit water to recover turbine pressure
  - Adjustable guide vanes for higher efficiency
- **Cons**:
  - Requires a water Flow rate of $10m^3$/s
  - Requires a water head of $45m$
  - Vanes need to be angled to match the flow rate for optimum efficiency

Sources: Reference 11 & 12

Kaplan Turbines

•Primarily used in low head, high flow applications

•Adjustable blades for different flow conditions

•Capable of generating up to 200 MW in full size applications

Sources: Reference 13, 14 & 15

Kaplan Turbines

Analysis Related to Project Application

Kaplan Turbine

- **Pros**:
  - Adjustable guide vanes and blades can be adjusted based on individual flow characteristics
  - Vertical configuration allows for larger blade diameters
  - Direct connection to generators limits efficiency loss

- **Cons**:
  - Largest type of turbine, requires large space
  - Only efficient in high flow situation
  - Cavitation is common and detrimental to materials

Sources: Reference 13, 14 & 15

Alternator Assessment

- Power generation can be achieved through an alternator. Use rotating magnetic field that induces a voltage in the windings and the current is dependent on the position of the rotor.

- Types: Marine alternators, Automotive alternators, and Brushless alternators
- Relationship between speed and frequency is calculated by:

$$N = \frac{120f}{P}$$

Where P is the number of poles (usually even), f is frequency and N is RPM

Source: Reference 16

Choice of Alternator: Brushless

- Very similar to permanent magnet alternators (PMA)
- Eliminates having high RPM to generate power and outputs lower amperage but a higher voltage.
- Fewer moving parts
- Light weight
- Higher efficiency

Source: Reference 16

Battery Assessment

Marine Battery (Deep Cycle)

- Lead Acid (Deteriorates second quickest)
- Consistent, smooth, dependable electricity
- Ideal for expending low power over long periods of time
- Typically two thick charge plates; holds large quantities of charge

Car Battery (Short Cycle)

- Lead Acid (Deteriorate at the quickest rate)
- Built to provide high bursts of energy over short periods of time(like in starting an engine)
- Charge and discharge rates very high, (split up into 6 plates)

Lithium-Ion Battery

- Very light weigh (150 kwh/kg) as opposed to 1 kwh/6kg of lead acid battery
- Deteriorates very slowly, (2 times life of lead-acid)
- Can be dangerous as they are highly reactive
- Because of this requires a charge controller(additional cost)
- Inherently a bit dangerous if over heated

Source: Reference 17

Lead Acid vs. Lithium-ion

	Lead Acid	Lithium Ion
Energy Density (Wh/L)	100	250
Specific Energy (Wh/kg)	40	150
Regular Maintenance	No	No
Cycle Life	1,000 @ 50% DoD	1,900 @ 80% DoD
Typical State of Charge Window	50%	80%
Temperature Sensitivity	Degrades above 30°C	Degrades above 45°C
Efficiency	100% @20-hr rate 80% @4-hr rate 60% @1-hr rate	100% @20-hr rate 99% @4-hr rate 92% @1-hr rate

Source: Reference 17

Anchoring Assessment

Submergible Portion:

- **Scoop/Plow Style**
  - Anchor embeds itself under river bottom
  - Best used in rocky and high-vegetation bottoms
  - Uses direction of flow to dig deeper for better securement

Danforth Style

- **Traditional anchor as seen with boating applications**
- **Sharp points of anchor embed deep into river bottoms consisting of mud and sand**

*Recommended to use both mentioned above together

Submergible Platform

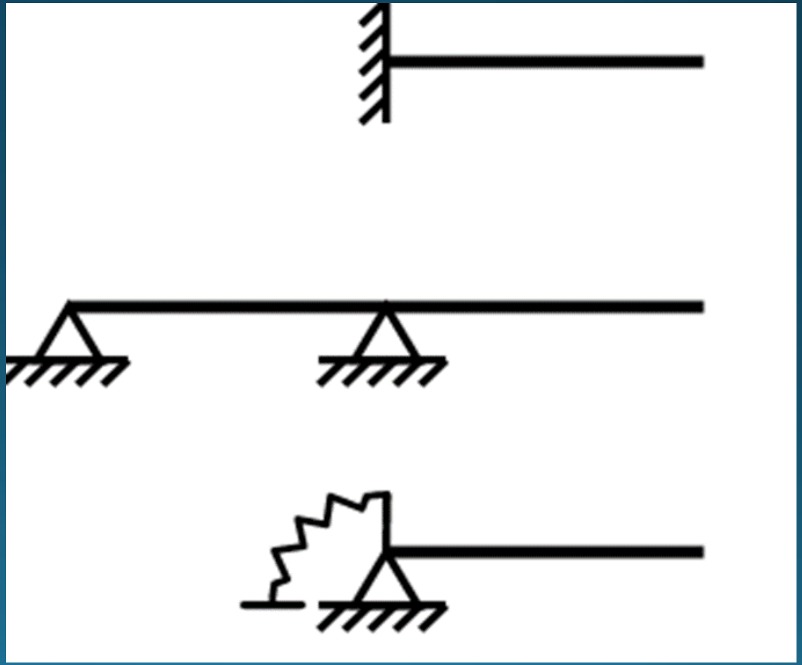
- **Use the weight of the apparatus to hold in place at the river bottom**
- **Method is easier than the others because of simplicity and less components**
- **A disadvantage consists of retrieving the apparatus from the water would be more difficult**

Source: Reference 18

Anchoring Assessment

Land Portion: Cantilever anchoring structure

This design allows the operator to install the generator from one side of the river as well as take away the uncomfortableness of entering the river water.



Conceptual Design

- Turbine Selection:
  - Kaplan Turbine
- Battery Selection:
  - Lithium Ion
- Alternator Selection:
  - Brushless
- Anchoring Selection:
  - Land-based cantilever system with possible upstream tension anchor point

Potential Challenges

- Heat dispersion
- Electrical equipment and components submerged in water
- Achieving proper gearing for RPM necessary for generator
- Waterproofing all components near water
- Submersing the apparatus at desired depth
- Overcoming the high amount of torsional forces acting on the land portion of the anchoring apparatus
- Keeping the design compact and easy to assemble

Plans for Progress

- Define turbine selection
- Optimize turbine selection through alternator selection
- Research different gearing options to achieve proper RPM and torque
- Conduct surveys to better understand the market need
- Contact vendors for pricing and availability
- Define battery selection
- Start producing CAD drawings to better define prototype dimensions
- Define anchoring systems through force analysis
- Research housing and material options to make waterproof and durable
- Inverter implementation

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