Final Paper
Team 9: Runoff Power Generation (RPG)
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**How Might We? Statement**

How might we increase renewable energy production by diversifying our energy sources?

## THE PROBLEM

Problem Statement and Significance:

Over the past century, global temperatures have been rising in a phenomenon commonly known as "global warming" [1]. This occurrence is caused by so called "greenhouse gases" released into our atmosphere by the burning of fossil fuels for energy. These gases trap the sun's heat and are increasing the global temperature at an unprecedented rate [2]. According to the World Bank, if global temperatures rise by just 4 degrees Celsius in the next century, widespread crop failures and malnutrition will pose a serious threat to populations throughout the world [3]. In addition to the current issues with global warming, energy demand is expected to increase by over 50% by 2040, further exacerbating the problem [4].

Context of the Problem:

To combat this pressing issue, energy that can be generated without producing these harmful greenhouse gases is being emphasized throughout the developed world. Unfortunately, only 9.81% of energy consumption in the United States comes from renewable energy sources, and even less from true green energy sources with no negative by-products [5]. One of the reasons for the low penetration of renewable energy sources is their innate intermittency and unpredictability. Matching the demand for energy with the supply is very difficult with current renewable energy technology [6]. In order to change the trend in both global temperatures and energy infrastructure, alternative renewable energy sources must be considered.

## THE SOLUTION

Goal:

RPG's goal is to build a system to collect rainwater runoff from a bridge and use the potential energy of the water to turn a turbine and generate electricity. The electricity created in this process will be used to power building in the immediate area. **The scope** of the project is reducing the world's dependence on fossil fuels for energy by addressing the intermittency and storage issues associated with many existing renewable resources and diversifying the renewable energy market [6]. **The rationale** for the project is that since a reliance on fossil fuels aggravates global warming by creating greenhouse gases, our device works to limit our dependency by creating an alternative source of energy, one that doesn't contribute to global warming. The US Government has mandated that utility companies must generate 20% of their power from renewable sources by 2020. Our project will help the utility companies to take a step towards that goal [7]. **The impact** of the project will start small-scale but has the potential to expand

from a local level to a major nationwide initiative. The project will diversify the green energy market and will complement solar energy and wind power by generating power on-demand, thereby reducing intermittency. If our system consistently produces 14,000 kWh for 20 years with a total installation and maintenance cost during that time period of $24,000, then the estimated cost will be 8.57 cents/kWh compared with PV Solar's cost of 15.6 cents/kWh.

Solution Description:

The basic principle behind the solution developed by Runoff Power Generation is that the potential energy of rainwater runoff, a common sight in the built environment around the world, can be a significant source of green energy. RPG's system collects rainwater that falls on the bridge in a storage tank located below the roadway. From the tank, the water is released and flows down through a main outflow pipe to the ground and turns a turbine, thereby generating electricity. A spear valve will be used to regulate flow rate at the bottom of the system and optimize jet velocity for maximum power output.

Objectives and Status Update:

Objective 1: Create Design Document

1. *Create CAD models* – The basic conceptual CAD model has been completed, but the group is still working on a detailed model for the system and its parts.
2. *Determine which materials would be most cost-effective for each component of the system* – The group created a hypothetical list of materials and services, but this still needs to be revisited once the group has more information about the bridge and set long-term goals. This task has been reduced in priority and efforts are focused on the prototype.
3. *Perform fluid mechanics analysis on the system* – This has not yet been completed. The group has discussed fluid mechanics with Fluid Mechanics professor James Dixon. The team is awaiting blueprints and exact final dimensions for the bridge. Calculations will be started during prototype development to test theoretical model. A spreadsheet was created to calculate flow rate in an ideal system. This will be used as a checking method during detailed calculations.
    a. *Calculate head loss based on diameter and number of turns of the pipe*
    b. *Calculate optimum nozzle, turbine, and generator size based on pressure at the base of the bridge*
    c. *Calculate effects of sloshing from bridge vibrations and movement*
4. *Finish design document explaining details of design, its components, functions, and features* – This has not been started. This has been postponed until the testing of the prototype has occurred.
5. *Begin patenting process* – The provisional patent application will be started in Summer 2014. The group has contacted a patent lawyer in Washington, D.C. who will help with the process.

Objective 2: Build Prototype

1. *Construct a working prototype that will prove the concept of generating energy from elevated tank and Pelton wheel* – This is in progress. The team will work on a previously

constructed prototype in Washington, D.C. in order to get measurements during Summer 2014.

2. *Obtain funding for prototype* – The group is competing in Ideas2Serve for prize, as well as searching for other sources such as the P3 Grant sponsored by the U.S. Environmental Protection Agency.
    a. Competed in the Ideas2Serve competition in April.
    b. Presented project at the Georgia Tech Energy Expo to raise awareness about project in April.
3. *Build small-scale prototype* - This prototype will demonstrate feasibility of energy capture method and test theoretical model of efficiency and water flow. This will be done over the summer in Washington DC.
4. *Create a small-scale 3-D print of the system and bridge* – This has not been started. This will be completed after the prototype has been completed and calculations have been performed
5. *Design a construction plan for the first functional prototype system on the New River Gorge Bridge* – This has not been started. This will be completed after the prototype has been completed and calculations have been performed
6. *Build the first completely functional prototype system on New River Gorge Bridge* – This will be planned once the small-scale prototype is completed.

How has your project changed over time?

Last semester, our focus was building this system on residential buildings. After feasibility calculations, it was found that bridges to be more cost-effective because of the larger scale. Therefore, the group decided to pursue the new project. Earlier this semester, the group was focusing on working towards implementing our first prototype on the New River Gorge Bridge. However, it was determined that a smaller-scale prototype needed to be constructed before implementing the project on such a large bridge. The smaller-scale prototype will be used to optimize the system.

**FUTURE**

Future Implications and Next Steps:

The team is planning to continue with the project. In Summer 2014, the patenting process will be started, the small-scale prototype will be constructed, and the group will make a website. The website will provide information about our project and will be useful when applying for funding in the future. It will also be useful when introducing the project to those who will decide if our project will be implemented on the New River Gorge Bridge or other bridges. In Fall 2014 the provisional patent application will be filed, the design document will be completed, the group will start planning for the utility patent, and the group will be in contact with the people who manage the New River Gorge Bridge. In the far future, the group wants to have the system implemented on the New River Gorge Bridge as well as several other bridges. The group has identified several potential sources of funding for the future. There are grants available from EPA, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, and other federal agencies that RPG will consider for funding. The group also plans to participate in competitions like Georgia Tech's Inventure Prize and the EPA's P3 Student Design Competition.

**Sources:**


[1] J. Gillis, "Global Temperatures Highest in 4,000 Years," The New York Times, 7 March 2013.

[2] "Causes of Global Warming," National Geographic, 27 September 2013.

[3] "World Bank warns of '4-degree' threshold of global temperature increase," The Washington Post, 19 November 2012. [Online]. Available: http://www.washingtonpost.com/business/economy/world-bank-warns-of-4-degree-threshhold/2012/11/19/aa298dd0-3023-11e2-a30e-5ca76eeec857_story.html

[4] "International Energy Outlook 2013," EIA.gov, 25 July 2013. [Online]. Available: http://www.eia.gov/forecasts/ieo/world.cfm

[5] K. Bossong, "Renewable Energy Mid-Year Report: 10% US Energy Consumption, 14% Net Electrical Generation," RenewableEnergyWorld.com, 30 September 2013. [Online]. Available: http://www.renewableenergyworld.com/rea/news/article/2013/09/renewable-energy-mid-year-report-10-us-energy-consumption-14-net-electrical-generation.

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[7] "Annual Energy Outlook 2014," Energy Information Administration, 7 April 2014. [Online].
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