EDMONDS COMMUNITY COLLEGE

Tidal Power

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Abstract

Tidal power converts the hydrokinetic energy of changing tides into mechanical energy for electricity generation. Tidal energy should be further researched and implemented in increasing scales to develop a price competitive and ecologically friendly supply of renewable energy. Tidal power has the potential of being an excellent source of reliable, green energy. The issues of financial, construction, and environmental feasibilities are three of the largest concerns.

The monetary costs in the early stages are high. Once researched and developed tidal energy should become a price-competitive form of renewable energy. The stresses of the marine environment complicate development but will fade as the technologies and materials are expanded and established. The environmental effects of removing energy from tidal currents are unknown. Careful observation and regulations will have to accompany the development of tidal power.

The costs are high, the stresses are considerable, and the environmental impacts are yet unknown. But the benefits of developing this potentially vast source of green renewable energy make the technology worth the effort. Something has to be done, we cannot let the increasing trend of fossil fuel consumption continue and despite the challenges tidal power may provide a better way.

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Executive Summary

Tidal Power converts the hydrokinetic energy of changing tides into mechanical energy for electricity generation. Fueled by the perpetual motion of the moon orbiting about the earth, the tides will flow so long as the heavens are in orbit. Engineers desire to harness this power as an alternative to burning our finite and environmentally damaging fossil fuels. Tidal energy should be further researched and implemented in increasing scales to develop a price competitive and ecologically friendly supply of renewable energy.

Tidal power has the potential of being an excellent source of reliable, green energy. The issues of financial, construction, and environmental feasibility are three of the largest concerns.

The monetary costs in the early stages are high. Fossil fuels have less upfront cost and the technologies are readily available. Tidal in stream generators are a new technology and are still in the expensive prototyping stage. Once researched and developed tidal energy should become a price-competitive form of renewable energy.

The stresses of the marine environment complicate the development of in stream tidal generators. Corrosion, biofouling, and durability are three stresses innate to maritime constructions and require new technologies, materials, and designs to overcome. Like the financial challenge, the hindrances of sea stresses will fade as tidal power becomes better established.

The environmental effects of removing energy from tidal currents are unknown. It is feared that the effects of extracting energy from the tidal streams may cause great environmental damage. These effects have not yet been seen, and will unlikely remain unseen until tidal plants near full commercial size. Careful observation and regulations will have to accompany the development of tidal power.

The costs are high, the stresses are considerable, and the environmental impacts are yet unknown. But the benefits of developing this potentially vast source of green renewable energy make the technology worth the effort. Something has to be done, we cannot let the increasing trend of fossil fuel consumption continue and despite the challenges tidal power may provide a better way. Therefore I propose continued support and development of tidal power as a renewable energy source.

Introduction

Purpose

This report analyzes the use of tidal currents as a renewable energy resource. Tidal energy should be further researched and implemented in increasing scales to develop a price competitive and ecologically friendly supply of renewable energy. Tidal energy is a clean power source that does not emit CO_2 and therefore benefits the whole world. However, since tidal energy harnesses the powers of the tides it will most directly impact the countries on the ocean that can employ the technology. In recent times, hundreds of millions if not a few billion US dollars have been invested worldwide in an effort to develop tidal technologies. There are, however, many concerns about the practical feasibility of tidal energy systems and whether or not they are worth the investment. This report details the development, benefits, and controversy of tidal energy.

Background

Renewable resources are defined as natural resources that will regenerate faster than we can deplete them. Tides are caused by the gravitational attraction of the moon and sun pulling the oceans as the earth rotates and the planets orbit. Therefore the tides will flow so long as the heavens remain in orbit.

As the world turns, the demand for energy increases. Worldwide, fossil fuels provide 85% of that energy. The consumption of fossil fuels is one of the major concerns facing engineers today. Fossil fuel consumption is a leading contributor to greenhouse gasses and is an unsustainable source of energy. Currently, renewable resources account for about 9% of the energy produced worldwide and their market share is expected to grow to 11% by 2030 (International).

Many countries are making large renewable obligations –declaring that a certain percentage of their energy will come from renewable resources— and taking great steps towards green energy as shown in the following quote: “The U.S., Europe, China and South Korea lead global renewable energy spending plans after committing about $500 billion to push 'green' technologies under wider plans to stimulate their own economies” (Renewable).

The United Kingdom House of Common’s *Science and Technology: Seventh Report* gives us an idea of the scope of this resource: “If less than 0.1% of the renewable energy within the oceans could be converted into electricity it would satisfy the present world demand for energy more than five times over"(Science). Tapping the tidal energy would divert energy from the movement of waters in the tidal flows but would not diminish the source, gravity. Tidal energy is essentially inexhaustible but the feasibility and effects of extraction are unknown.

Methodology

There are many theoretical ways to extract power from the movement of the oceans. Few have been tested. There are two leading methods currently employed by engineers around the world, tidal barrage and tidal stream generators.

There are currently 5 tidal barrage power plants around the world. Tidal barrage plants are essentially dams across the mouths of estuaries, basins, or bays where tides create large potential differences. Like a river dam; tidal barrages use the potential gravitational difference between two bodies of water to power turbines. Tidal barrages are efficient and reliable sources of electricity but require a large initial investment. Their ecological footprint has been a cause of concern for many; the damage to local sea life and local flora and fauna are two large concerns for this type of power generation.

Where tidal barrages are analogous to dams, tidal stream generators are like underwater windmills. Tidal stream technology has grown in great leaps and bounds in the last ten years and several full size units have recently been deployed. Tidal stream technology can be employed in any waterway with, "a mean spring peak velocity exceeding 2.25–2.5 m/s in a 30–40m depth of water" (Douglas).
There are many such locations around the world, and locally the Puget Sound is considered one of the best locations on the West Coast.

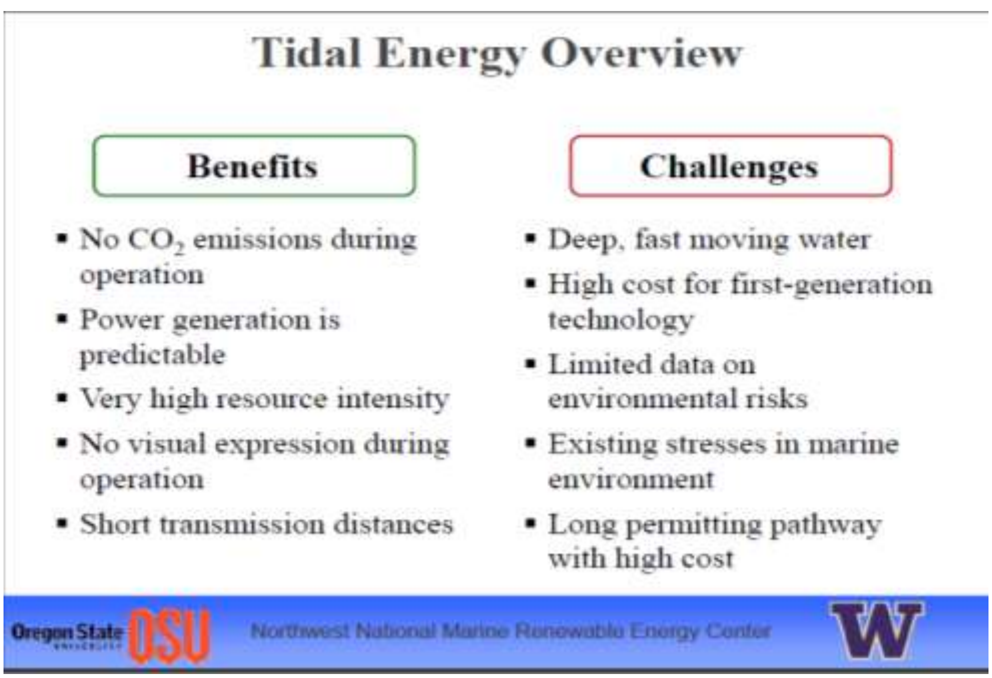
Tidal stream generators pose to capture a large portion of the energy market in sea-bordering areas. The rest of this report will focus on the in-stream tidal power technologies.

Discussion

The concept of tidal power is too attractive to deny, but there are many challenges. Let us briefly discuss the benefits, and thoroughly review the challenges. Tidal power has the potential to be an excellent source of reliable, green energy. The issues of financial, construction, and environmental feasibility are three of the largest concerns.

In his presentation, *Riding the Tide: Tidal Power Development in Puget Sound* Brian Polagye of the Northwest National Marine Renewable Energy Center (NNMREC) University of Washington Tidal Energy Branch lists the benefits and challenges as follows:

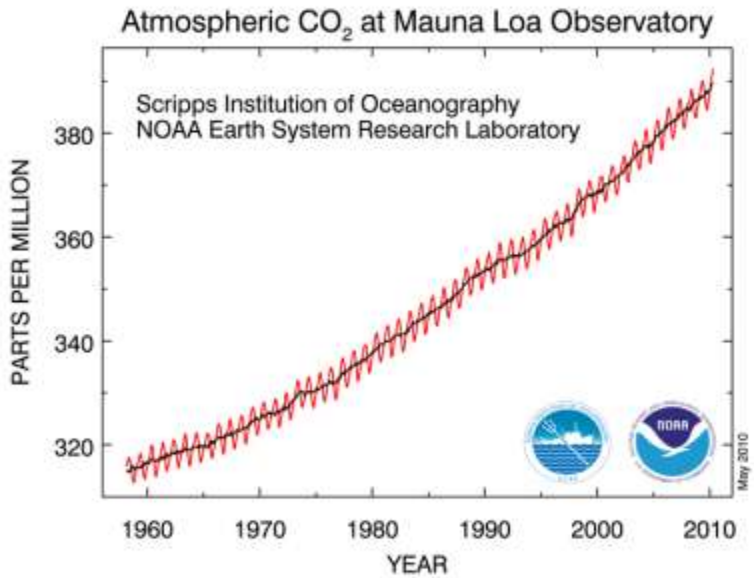
Figure 1 Benefits and Challenges (Polagye)



The table lists the substantial benefits of tidal power and the imposing challenges. We will discuss the "no CO_2 emissions during operation" and "power generation is predictable" benefits and the challenges of “high cost for first-generation technology, existing stresses in marine environment, and limited data on environmental risks” (Polagye).

In addition to being a renewable power resource, the absence of CO_2 emissions during operation and the predictability of power generation are large benefits. The alarming increase in atmospheric CO_2 is clearly visible in the following graph.

Figure 2 Atmospheric $C0_2$ (Tans).



Sixty-four percent of atmospheric carbon dioxide is attributed to the combustion of fossil fuels. Without drastic policy changes worldwide carbon dioxide emissions are expected to grow 39% in the next twenty years (“frequently”). The figures are staggering; reducing carbon emissions is a huge benefit of tidal energy.

The environmental benefits of pursuing green, renewable energies are further augmented by the reliability of the tides. For thousands of years humans have been able to accurately predict the tidal patterns. Unlike wind or solar, we should be able to predict when and how much energy the tidal generators will produce for months and years in advance.

The cost, sea stresses, and environmental concerns may ultimately outweigh the benefits and are therefore the focus of the discussion section of this paper.

Cost

Is tidal energy financially feasible? One of the major concerns with tidal energy is that the technology is too young and underdeveloped. The expenses range from site characterization, technological development, permission, construction, installation, environmental monitoring, repairs, and going back to the drawing board when aspects fail.

Verdant Power recently installed six in stream tidal generators in the East River New York; the expenses of pioneering a technology are clear in the following quote. “To date, Verdant has generated 50 MW of electricity – at the cost of US$12 million, including US$2 million on high-tech fish monitoring equipment as specified by the Environmental Protection Agency” (Block). One sixth or nearly 17% of their expenses went into watching fish. Such environmental concerns are important but costly. Also evident in this quote is the resolve of companies like Verdant Power to not let these upfront costs stop them.

Roger Bedard, the Ocean Energy Leader at the Electric Power Research Institute (EPRI), sets forth this chart for comparison of tidal In-stream and other current energy sources.

The capital cost is the cost of initial construction and major plant modifications. This capital cost is one of the most significant factors for investors. In the long run, the cost of electricity (COE) and $C0_2$ are more important to some.

The COE in column four is defined as:

$$\frac{\text{(total plan cost x fixed charge rate) + annual operation and maintenance}}{\text{annual energy produced}}$$

Figure 3 Comparative Costs (Bedard).

	Capital Cost (1) ($/MW)	COE (2)(cents/ kWh)	CO2 (lbs per MWh)
Tidal In-stream Power Den > 3.0 Power Den 1.5-3.0 Power < 1.5 kW/m2	 1.7-2.0 2.1-2.4 3.3-4.0	 4 – 7 4 – 11 6 - 12	 None None None
Wind (class 3- 6)	1.2 – 1.6	4.7-6.5	None
Solar Thermal Trough	3.3	18	None
Coal PC USC (2)	1.3	4.2	1760
NGCC @ $5/MM BTU (3)	0.5	4.8	860
NGCC @ $7/MM BTU (3)	0.5	6.4	860
IGCC with CO2 Capture (4)	1.9	6.1	344

NGCC: natural gas combined cycle

(1) All costs in 2005 US$
(2) 600 MW plant, Pittsburgh #* Coal
(3) GE 7 F machine or equivalent
(4) 80% CO_2 removal

Comparative Costs

The table shows that the capital cost for tidal in-stream systems can be higher than fossil fuel alternatives. These figures are based on tidal in-stream systems currently in use. As technology improves, the cost of tidal in-stream generators should continue to drop. For example, Aaron Davidson and Craig Hill of Tidal Energy Pty Ltd engineered a turbine to use shrouding and the venture effect to increase the efficiency of their turbine by as much as 3.84%. “All installations are site dependent but the DHV Turbine can supply power to the grid for as little as US$0.03 - US0.05 cents per kW (depending on the site) and is able to run with a minimum of service due to the simplified design of very few working parts.” Such advancements might drastically change the feasibility of tidal power. In *Venturi: Diffuser Augmented Water Current Turbine* inventor Aaron Davidson explains:

"As the greatest costs in any water current turbine deployment are the costs of physically placing the turbine in the water and not the overall cost of the manufacture and fabrication of the turbine and venture; having a system with high output reduces the payback timeline of capital outlay making the DHV significantly attractive to potential investors as 3-4 open or free stream turbines of similar size would be needed to match the output of just one DHV Turbine". (Davidson)

Such advancements might soon make tidal energy the most cost-effective energy source. Bedard of the EPRI is quick to point out that "the entry point for a TISEC plant is much less than that of a wind plant back in the 1970s and early 1980s (i.e., over 20 cents/kWh)." Tidal power has benefited from the substantial research and investments in wind technologies, the general advancement in materials science in the past forty years.

Once over the initial investment hump, tidal generators should have extremely low maintenance costs and produce electricity very economically. Right now each unit is essentially made by hand. As production increases "value engineering and economies of scale" will further decrease costs (Bedard).

The concern is that tidal stream systems are not cost effective. The rebuttal is that the systems are readily becoming cost effective as technology improves. If the technology becomes financially feasible will the turbines be able to withstand the stresses from being in the ocean?

Sea Stresses

For tidal power to become a feasible source of electricity the tidal stream devices have to withstand the varied stresses inherent with their saltwater environment. Three primary concerns are corrosion, biofouling, and durability.

Corrosion

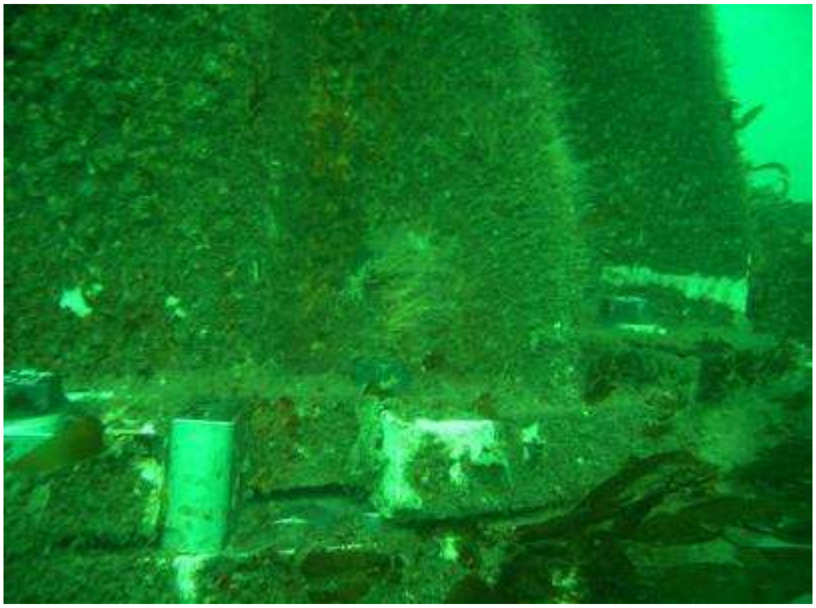
Corrosion limits the materials available but is more of a financial concern than a mechanical feasibility concern. Most common construction materials rapidly degrade in saltwater. However, the University of Washington found that, "Stainless steel, glass fiber composite, and carbon fiber composite did not visually degrade over the test duration" (Thomson). Corrosion poses a challenge for designers but will not be a deciding factor in the feasibility of tidal power, just a developmental obstacle. Designing such devices increases the cost of production substantially. The piling and housing can be built with materials familiar to the marine industry, specifically offshore oil platforms. The complication comes with the moving parts that have to remain aerodynamic for efficiency purposes.

Biofouling

Biofouling has proved a more difficult setback. Biofouling decreases the efficiency of the turbines and can interfere with the generator, electric connections, and the moving parts of the turbine. New materials and protective coatings are being developed to resist such fouling.

Biofouling is location specific and is especially bad in the photic zone (where light penetrates and algae and sea vegetation thrive) of the ocean. The following image is of biofouling on a Clean Current tidal energy turbine deployed at Race Rocks Ecological Reserve on the southern tip of Vancouver Island BC.

Figure 4 Biofouling (Race Rocks).



As seen pictured above, biofouling can cover tidal generators within months. For tidal power to become a mainstream source of electricity the generators have to be able to operate for many years with little maintenance. The location of tidal generators in high intensity tidal flow zones not only complicates maintenance but also requires very sturdy construction.

Durability

Tidal generators must be strong enough to withstand the power of the tides that they are designed to harness. The strength of the tide has surprised Verdant power, "the company had to twice go back to the drawing board when the tide first ripped off the blades, and then the bolt connection to the hub" (Block). Durability should not be a long term issue but is a developmental concern.

Environmental

Once technical issues such as cost and ability to withstand maritime stresses have been addressed, environmental concerns take the forefront. The environmental effect of extracting kinetic energy from tidal streams is an issue of great debate.

Even if engineers could cost effectively extract energy from the tides, what will the effects of such extraction be? Hans van Haren of newscientist.com comments, "The vastness of the ocean has always created the illusion of infinite resources, whether for food or waste disposal. Yet despite its huge size, the ocean is vulnerable to exploitation." He then goes on to detail how removing the kinetic energy from tidal currents, "will have devastating effects on the ocean ecosystem" (van Haren).

By extracting large amounts of energy from tidal streams we run the risk of changing tidal patterns. As less water is carried downstream, sea life and vegetation may not be able to adapt. If the environmental concerns are actualized in larger scale tidal farms, this technology would be self defeating. The benefits of tidal energy are its green and renewable characteristics, unless the environmental impact is further researched and monitored, we won't know whether the technology is truly helping or hurting us more.

That is the fear. Will the effects be local, carry far upstream, or be global? Some companies expect to harvest up to twenty percent of the hydrokinetic energy from some tidal streams. There preliminary research has led them to believe that this is the ideal amount to extract without serious side effects.

The Electric Power Research Institute believes that “Given proper care in site planning, in-stream tidal power promises to be one of the more environmentally benign electrical generation technologies“(Bedard). There opinion is shared by many tidal power developers and supporters.

There is great concern, and many theories, but little experimental evidence. The findings note the progress of some tidal current generators already in use. But the environmental impact will not be realized until projects of increasingly large scales are built and begin to remove significant amounts of energy from tidal flows.

Findings

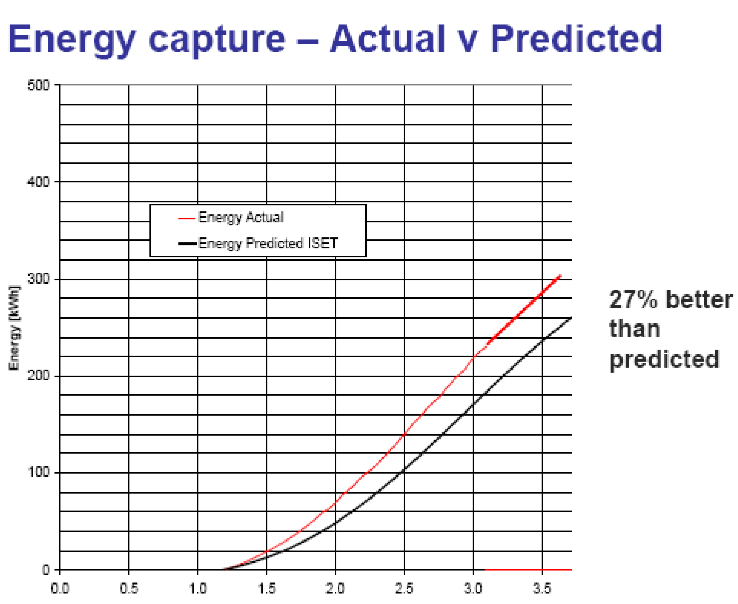
Corrosion, biofouling, and durability are appreciable obstacles for engineers. However, as technology advances these issues should be surmountable. Current tidal generators have been in operation for as many as four years with successful operation and minimal fouling. The success of such projects has increased interest, investment and optimism for the future of tidal power.

The SeaGen is a full scale in stream tidal energy converter built and designed by the United Kingdom company Marine Current Turbines; it has been in use since 2008 and has had little corrosion or biofouling (Douglas).

Similarly Verdant Power’s tidal turbine installed in the East River of New York has been in operation for over two years and shows no signs of “fouling or damage from debris” (Verdant).

The Lynmouth **Seaflow** has now run successfully for over three years operating completely unattended and controlled remotely and generating 27% more electricity than predicted (“Worlds”).

Figure 5 Seaflow Energy Capture (“worlds”).



Such optimistic beginnings encourage continued research and development.

Recommendations

Will the challenges of cost, sea stresses, and the unknown environmental impact restrain tidal energy from becoming a major source of electrical generation? We cannot know until more full scale projects are built and observed. Many seem to have "caught the tide" and early findings are promising but limited.

The monetary costs of these early stages are high but once researched and developed the operation costs should be relatively low. As the technology matures and productions of scale reduce the upfront cost tidal energy could become a price-competitive form of renewable energy.

The stresses inherent to the marine world have posed a great challenge for early-developers. As with the financial feasibility, this problem will diminish as the technology matures. The sea stresses increase the difficulty of designing a price-competitive technology. Further research in materials and technological advances will diminish this concern.

The chief concern facing tidal energy projects is the questionable environmental impact. Preliminary findings have not verified this concern. The detrimental effects will likely not be realized until larger tidal power plants are constructed. To minimize these effects it is crucial that environmental scientists company the development of tidal power at every step. Small scale production plants are unlikely to cause considerable damage to their environments, only as the plants grow will we know if tidal power is environmentally feasible.

The costs are high, the stresses are considerable, and the environmental impacts are yet unknown. But the benefits of developing this potentially vast source of green renewable energy make the technology worth the effort. Something has to be done, we cannot let the increasing trend of fossil fuel consumption continue and despite the challenges tidal power may provide a better way.

Conclusion

Tidal energy should be further researched and implemented in increasing scales to develop a price competitive, technically sound, and environmentally friendly supply of renewable energy. If we do not pursue green and sustainable energy sources today, we will ruin the planet for tomorrow. Tidal power technology is young but is growing rapidly. If in stream generators are further developed we can expect to see tidal energy supply a notable amount of energy for ocean-bordering countries.

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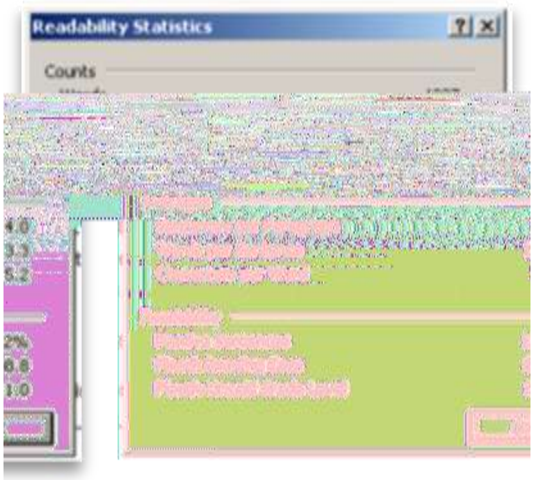
Appendices

Appendix A: Fog Index



Appendix B: Author Biography

The author has been called a villain by some a hero by others. He rides the streets of Edmonds in the early morning and late at night. His bike is a dandy she's been with him since 1999, she takes a lickin but keeps on kickin. He's a country boy at heart and likes to spend his time out in the woods or in the shop. Someday he just might have a place back in the rugged Cascade Mountains all of his own. But that might have to wait until he's traveled the world and found a lady and/or a dog. Today he will type until midnight, tomorrow he will stuff some portabella mushrooms and paint his cousins house, the day after he will interview for an intern exchange program to England. So the next time you see a bicyclist strapped with an awkward burden of backpack and plastic bags, give him 3 feet or he might just free-write about you in his next biography, and it won't be pretty.

Glossary

Term or Abbreviation	Definition
Turbine	any of various machines having a rotor, usually with vanes or blades, driven by the pressure, momentum, or reactive thrust of a moving fluid
hydrokinetic	Of or relating to the kinetic energy and motion of fluids.
Kinetic energy	the energy of a body or a system with respect to the motion of the body or of the particles in the system.
Corrosion	a state of deterioration in metals caused by oxidation or chemical action (1)
Biofouling	the undesirable accumulation of microorganisms, plants, algae, and/or animals on wetted structures (2)
EPRI	Electric Power Research Institute
NNMREC	Northwest National Marine Renewable Energy Center

(1) See works cited ("Corrosion") (2) see works cited ("biofouling")

*All other definitions come from dictionary.com ("dictionary").