PROSPECTS OF ELECTRICITY FROM TIDAL POWER IN COASTAL REGIONS OF BANGLADESH

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ABSTRACT

Electricity from tidal power is a form of pollution free renewable energy which has a lot of potential. This potential has not been realised yet, due to two major problems–high capital costs and environmental concerns. This paper discusses how the two problems could be resolved utilising small-scale technologies, innovative financing, and involving local communities to ensure that all key impacts are manageable. Bangladesh has a long coastal area with 2~8 m tidal head/height rise and fall, most of which is protected against flooding by embankment and sluice gates. Therefore, the potential for tidal power in the country is significant because the barrages necessary for creating controlled flow through turbines (to tap tidal power) are also needed for flood control. This paper will discuss a proposal for “Integrated Tidal Power and Coastal Development”.

Introduction

Tidal power is not a new concept and has been used in Britain and France since at least the 11th Century for milling grains (ACRE, 1999). Oceans cover over 70% of the earth's surface and the energy contained in waves and tidal movements is enormous. It has been estimated that if less than 0.1% of the renewable energy available within the oceans could be converted into electricity it would satisfy the present world demand for energy more than five times over (Wavegen, 1999).

However, tidal power remains well below its potential in terms of application. Presently, tidal plants exist only in France since 1967 (La Rance), Canada since 1984 (Annapolis Royal), and in China (the Bay of Kislaya and Jiangxia Creek). Many tidal projects are being considered today including the seven projects in England, Derby Hydro Power of Western Australia: (48 MW); Corova, south coast of Alaska; Southern portion of Chile; Gujarat, India: (1000 MW); Mexico: (500 MW); the Philippines: (2200 MW) and China: (20,000 MW) (Tidal Electric Inc, 1999; Green Energy, 1999; ACRE, 1999).

The usual technique in harnessing the tide is to dam a tidally-affected estuary or inlet, allowing the incoming tide to enter the inlet unimpeded and then using the impounded water to generate power. The main barriers to uptake of the technology are environmental concerns and high capital costs. In recent years, these problems have been mitigated considerably by design, by involvement of experts and local communities in the identification and installation of new plant, and by a growing understanding of how to achieve more sustainable energy development. However there have been very few studies in the academic literature that analyze this process of how a new form of sustainable energy has been changing to become more mainstream and acceptable (Baker, 1991).

Generally speaking, it is quite possible to harness energy from the tides; however the technology is not yet practically and commercially available; there are also environmental concerns. Therefore, until now, tidal power generating issues have not been substantively addressed. The attempts to achieve environmental resolution will be the primary focus of this paper. The other major problem of high capital costs will also be addressed. Like hydro schemes, tidal power has high capital costs due to the large scale of engineering involved, but involves low operating costs. Tidal power has the extra problem of having to be located in a coastal environment where engineering is likely to be even more costly due to the changeability of the coast. However, there is no research that has been conducted yet where the coastal engineering infrastructure is already present (like Bangladesh Coastal Islands). This paper also suggests how tidal power can be harnessed in Bangladesh, where the necessary engineering (coastal embankment and sluice gates) infrastructure already exists.

Tides and Tidal Power

The gravitational forces of the sun and the moon on the rotating earth causes the ocean’s water to bulge upwards, resulting in tides with two high tides occurring every 24 hours and 50 minutes; every rise and fall stores a large amount of potential energy.

The energy of the tides comes from the rotational energy of the earth (Derby Hydro, 1999).

Tidal energy is generated from the power of the changing tides, called tidal range (the difference between height of high tide and low tide point). This tidal change in sea level can be used to generate electricity by building a dam across a coastal bay or estuary with large differences between low and high tides. The high tides allow immense amounts of water to rush into the bay. The gates (sluice gate) of the dam are then shut when water level is at its maximum height. Outlets in the bottom of the dam allow water (at great speed and pressure) to rush past the turbines. The flow of water generates enough power to turn the turbines which, in turn, creates electricity. The generation of electricity from tides is very similar to hydroelectricity generation, except that water is able to flow in both directions and electricity is created utilizing two-way turbines.

The tidal range varies throughout the lunar month according to changes in relative positions of the sun, the earth and the moon. When the sun, the earth and the moon line up (twice monthly), the two daily high tides are extra high and give the largest tidal ranges of the month, called Spring Tidal Range (ACRE, 1999). Tidal power stations can be stretched over deltas, estuaries, beaches, or other places that are affected by the tides.

Benefits of Tidal Power

The key benefits of tidal power are:

Economic

Tidal power has been used, to a limited extent, over several centuries, but only recently has any significant effort been put forth to realising its vast potential. Today, sites suitable for the utilization of tidal power exist in many places around the world. Except for the fact that it involves massive capital outlays, tidal power can result in extremely low costs per Kw.hr once it is built.

Renewability

Although not entirely solar (as it is mostly lunar power), tidal energy is truly renewable. Long after fossil fuels have gone, the tides will still be there (in an energy-hungry world and its escalating needs).

Predictability:

Unlike wind and solar energy, tidal power is entirely predictable. It, therefore, provides the potential to be used as a base-load power supply that is immune from climatic conditions and anthropogenic demands. For example, the amount of power generated is strongly related to the size of the tidal range. The output varies with the square of the tidal range, i.e., if a tidal range of x gives a power output of y, then a tidal range of 10x will give a power output of 100y. The power output is also directly related to the area of the impoundment structure that, in-turn, dictates the volume of water passing through the turbine during each generating phase. Tidal power generating equipment is also very efficient compared to other modes of power generation and, in general, the bigger the power generating equipment, the higher the efficiency.

Continuous power generation, that matches electricity demand, is an important characteristic of electricity supply. Generally, this is achieved through the continuous running of base-load generation equipment supplemented with peak-load generation equipment during peak periods. Nuclear power plants cannot be shut down quickly and are operated 24 hours per day and, therefore, nuclear power is a base-load type of power. Fossil fuels are somewhat easier to shutdown but typically they vent the steam to the atmosphere when demand for electricity declines at night. On the other hand, tidal power is a power source that can be shut down quickly and restored quickly without major losses in efficiency.

Very long term

The technology is very simple and has a potential life of more than 40 years. At least, that is the experience with tidal energy so far and there seems no reason to doubt the figures. Dams built in the Roman Empire Era still function today. Hoover Dam began power generation in 1936 and continues to function without any indications of potential failure. Thus it is reasonable to assume that tidal generators will last for many years, far beyond the normal 20 to 30 years life expectancy of other forms of power generation. Because the tidal generator uses no fuel and maintenance is minimal, the cost of electricity after the capital costs have been paid off in 15 or 20 years can be assumed to be nearly zero.

Other Benefits:

- It creates no pollution.
- Produces electricity 24 hours a day and 365 days a year.
- It is highly efficient (coal/oil efficiency = 30%, tidal power efficiency = 80%) according to Tidal Electric, 1999.

Problems with Tidal Power

There are two main reasons why tidal power has not yet been more fully developed.

Environmental concerns. The engineering of the coast is likely to be very controversial. The coast is important ecologically and socially and is (like most environmental boundaries) susceptible to change. Any engineering system on the coast raises significant questions.

High capital costs. Moving large amounts of coastal material so that the potential energy of tides can be tapped is inevitably going to involve high capital costs. Hydroelectricity generally involves high capital costs and coastal environments (being susceptible to change) are likely to need even more engineering.

Resolving the Problems with Tidal Power

Using small scale technologies:

A range of small scale tidal systems are now beginning to appear. These are tidal fences, tidal turbines and tidal mills. These systems have both lower capital cost and less environmental impact. They can also fit into small flood control channels like mini-hydro systems.

The problem with these small scale technologies is that mostly they do not develop the potential energy of a head of water that barrages provide. This means that they produce very little power. However, it is possible to link many small units in a geographically dispersed area if there is variation in tidal range across that area. The obvious application of small scale systems is to low income communities with no power (or very little power) and is very much applicable to coastal Bangladesh. For example, Alaska has significant tidal ranges along its southern coastline, making it an attractive site, particularly around Cook Inlet. Alaska’s economy is narrowly based on its oil and gas revenues, which have been declining in recent years. Forward-thinking government and business leaders see the vast potential of tidal power at Cook Inlet as a means of attracting new business and broadening the base of Alaska’s economy. Cheap, pollution free electricity is attractive to many industrial users and it offers a strong job-creation potential. For remote areas, decentralised diesel-powered generators, usually installed in a village schoolhouse generate most of Alaska’s power. Fuel must be transported in by any means available and, during the ice-bound winters, fuel is sometimes flown in or transported by snowmobiles. The cost of this power range from 25 to 80 cents per kilowatt-hour. However, Cook Inlet offers an opportunity to build small tidal generators (1 to 10 Megawatts), sized to the small populations, and free from the highly competitive energy market pressures. Preliminary discussions with interested parties in Alaska have proven very positive and Tidal Electrics is exploring the potential for a broad range of projects involving state and local entities, both public and private. This small-scale technology is a new and improved system for harnessing the ocean’s tides and that resolves the economic and environmental problems of barrage technology.

Innovative financing:

The capital costs of a tidal power plant are competitive with other power sources, in that the resulting electricity will be cheaper. The capital costs alone are higher, but the operating costs are considerably lower. Tidal power generation is highly cost-advantaged in respect to operating costs. However, large scale tidal systems still require innovative capital generation and cost recovery mechanisms, such as:

a. Extending pay backs over very long periods (much longer than normal loans) because of the reliability of the technology and certainty of the need for power. This is especially possible if they are jointly financed by the government and the private sector.
b. Providing special capital funds from government to meet greenhouse gas emission obligation, in a post Kyoto environment.
c. Recycling grants back into on-going renewable projects due to the low operation and maintenance costs of tidal generation.

Resolving environmental concerns:

The key ways to ease environmental concerns are to:

a. Involve the local community;

b. Ensure all key impacts are manageable on a scientific basis; and
c. Establish a global perspective as it is the global environment which is a major beneficiary of renewables.

The following example explains how the Derby Tidal Proposal of Western Australia is resolving environmental problems at their installation site.

a. Involving local community: The Derby project has from the beginning been extremely popular locally. It has touched the local imagination. A survey showed 96% of the local population supported the project and on a number of key occasions (politician visits) there have been large demonstrations showing their support. One feature of the project is that the aboriginal community has been backing the development. One reason (apart from the early consultation processes) is that the related aquaculture project is designed to employ 50 aboriginal people.

b. Ensuring all key impacts are manageable on a scientific basis: It could be possible to mitigate the negative environmental impacts for a particular project like Derby Tidal power project, by using Environmental Impact Assessment (EIA). In Derby, the environmental assessment process has been in place for the past 2 years. The EPA was able to resolve problems with sedimentation (back flushing can solve any potential build up), acid soils, wildlife, dust and other issues (EPA Report no. 942, 1999). Two important issues (mangroves and scientific interest) were resolved as follows:

Mangroves: The project will shift the flow of water along the tidal flats so it goes through the turbine. This will undoubtedly shift the mangroves but the best expert advice suggests that there will be an increase in the mangrove population, not a decrease. A similar barrage on the Fortescue River at Newman has increased tree life rather than destroying habitat as it trapped flood waters and directed them to aquifers. The tidal project will be shifting 5% of the mangroves in the area (0.7% of those in the north) and, according to a mangrove specialist at Murdoch, regrowth is not difficult on the new wetter areas.

Scientific Interest: The project is on a section of the coast with scientific interest, i.e., geologists have taken an interest in the layers revealed in the sediments. The body responsible for this is the Marine Parks and Reserves Authority and Barry Wilson the Chairman has said that they do not believe it is anything more special than other nearby areas. Also, the project will not alter the 'historical record' according to the EPA.

In the debate on these environmental matters some have suggested that small scale technologies would be more appropriate. However the amount of the power required makes it very difficult to tap this technology; an estimate of 24,000 small turbines has been suggested as being necessary to produce the same power if they were strung together. These would however only produce power when the tides were moving.

c. Seeing the global view : The Derby tidal project will produce greenhouse savings equivalent to 25% of Western Australia’s 2% "new renewables" target obligations. It will be an important signal that Australia can manage renewables on a reasonable scale (Derby Hydro, 1999).

Tidal Power Prospects in Coastal Bangladesh

Bangladesh is a country with low use of electricity (per capita consumption of 95 Kw.hr) and considerable need for development along its coastal area. Current electrification is estimated at only 16% of the population, with rural access of less than 5% (BCAS, 1998). This places Bangladesh's electrification rates amongst the lowest in the world. Bangladesh has a long coastal area (710 km) with 2~8 m tidal height/head rise and fall (table-1, BIWTA, 1999). It also has some large tidal sites and many channels of low tidal range in a large number of deltaic islands, where barrages and sluice gates already exist. Therefore, the potential for tidal power to be harnessed is significant, because the barrages necessary for creating controlled flow through turbines (to tap tidal power) are also needed for flood control. This avoids the problem of high capital cost as the engineering is either already there or is needed for cyclone protection.

Analysis of the following two tables indicate that Bangladesh has very good prospects for tidal energy, particularly in Sandwip.

The island of Sandwip is located in the Bay of Bengal, adjacent to Chittagong and is a mere 15 km from the mainland. The population is around 330,000 on an area of 240 km^2. The entire island is a mudflat created from the Ganges delta. A scoping visit to Sandwip was made in late November, 1999 by the Executive Agencies (Institute for Sustainability and Technology Policy (ISTP), International Centre for Application of Solar Energy (ICASE) and Tidal Energy Australia (TEA) assisted by the Rural Electrification Board and Grameen Shakti of Bangladesh.

This island is not a tourist haven and is also rarely visited by Bangladeshi's. The 5 m tides experienced at Sandwip results in poor accessibility, with the island constantly surrounded by mud flats, except during high tides. The island is subject to flooding from cyclones and in 1991 over one thousand people were drowned. A flood control barrage exists around the entire island and contains 28 sluice gates. A short electricity grid is also available linking the main commercial areas on the island. Two diesel generators of 200 KW run for a few hours late afternoon/early evening supplying electricity, mainly for commercial use. Some households have batteries and some diesel generators are used for powering rice threshers.

A photo voltaic (PV) system is used to maintain a fridge for vaccines in the health centre. The mud flats are composed of extremely rich soil, hence it is easy to grow a variety of food crops. The island is an exporter of rice and is largely self sufficient in vegetables and fruits. No aquaculture is conducted on the island, though shrimps are collected from the mud flats. None of the island's schools or colleges have electricity and opportunities for employment growth on the island are limited.

According to the scoping visit and expert analysis of different tidal range, Bangladesh may harness energy from coastal tidal resources by applying two technologies:

1. Low head tidal movements (2~5 m head); and
2. Medium head tidal movements (> 5 m head).

Table -- 1; Tidal levels in Coastal Bangladesh (BIWTA, 1999).

Station	LAT	MLWS	MLWN	ML	MHWN	MHWS	HAT	TD(AT)
Hiron Points	-0.256	0.225	0.905	1.700	2.495	3.175	3.656	3.912
Sundarikota	-0.553	0.036	0.636	1.829	3.022	3.694	4.211	4.764
Mongla	-0.261	0.325	1.194	2.310	3.427	4.296	4.882	5.143
Khal no. 10	-0.444	0.261	1.231	2.664	4.097	5.067	5.772	6.216
Sadarghat	-0.423	0.239	1.100	2.481	3.861	4.722	5.385	5.808
Cox's Bazar	-0.339	0.205	1.023	1.995	2.967	3.785	4.329	4.668
S. Island	-0.348	0.191	1.045	1.874	2.703	3.557	4.096	4.444
Sandwip	-0.583	0.238	1.634	3.243	4.851	6.248	7.070	7.653
Char Changa	-0.375	0.256	1.060	2.037	3.014	3.818	4.449	4.824
Khepupara	-0.323	0.195	1.025	2.060	3.096	3.925	4.445	4.768
C.Ramdaspur	-0.261	0.189	0.763	2.036	3.309	3.883	4.333	4.594
Barisal	+0.134	0.434	0.692	1.539	2.386	2.644	2.944	2.810
Chandpur	+0.019	0.256	0.493	2.172	3.852	4.088	4.326	4.307
Nalmuri	+0.078	0.370	0.722	2.195	3.669	4.021	4.313	4.235
Narayanganj	+0.458	0.585	0.697	2.770	4.844	4.956	5.083	4.625
Galachipa	-0.159	0.283	0.937	1.764	2.592	3.245	3.689	3.848
Patuakhali	-0.143	0.242	0.740	1.575	2.409	2.907	3.293	3.436

Explanation: MLWS = Mean Low Water Spring, MHWS = Mean High Water Spring, MHWN = Mean High Water Neap, MLWN = Mean Low Water Neap, ML = Mean Level, AT = Astronomical Tide, LAT = Lowest Astronomical Tide, HAT = Highest Astronomical Tide, TR = Difference between lowest and highest tidal height in "m".

Table -- 2; The main characteristics of the existing Tidal energy sites and examples of others that have been studied

(http://www.worldenergy.org/wec-geis/members-only/registered/open.plx?file=publications/default/c.../tidal.st)

Site	Mean Tidal	Basin Area	Installed	Design output	In-Service Date or Status
Rance (France)	8.0	17	240	540	1966
Kislogubsk (Russia)	2.4	2	0.4	1	1968
Jiangxia (China)	7.1	2	3.2	11	1980 (1st unit)
Annapolis (Canada)	6.4	6	20	50	1984
Severn (UK)	8.3	520	8600	14400	Studied
A8 Bay Fundy (Canada)	9.2	90	1400	3420	Studied
B6 Bay Fundy (Canada)	11.0	240	4864	14004	Studied
Garolin (Korea)	5.1	85	400	800	Studied
Kachch (India)	5.0	170	600	1600	Studied
Secure Bay (Australia)	5.2	94	740	1400	Studied
Walcott (Australia)	5.5	264	1750	3310	Studied
Mersey (UK)	6.5	60	700	3310	Studied

1. Low Head Tidal Movements:

Coastal Bangladesh, particularly Khulna, Barisal, Bagerhat, Satkhira and Cox's Bazar regions are, geographysically, extensively deltaic with levees and sluice gates. These areas are protected by embankments, which had been constructed during 1960s for protection from natural disasters like flooding and tidal surges. Therefore, the infrastructure needed for barrages and sluice gates is already present in this regions. These barrages and sluice gates may be used for electricity generation by applying simple technology. The proposal has three elements. Firstly, the use of an undershot paddlewheel with simple civil construction enabling the placement of the wheel at appropriate locations in the levees/barrages. The existing technology of undershot paddlewheels is historical, and generally uses a greater head as the energy source. Paddlewheels are generally not as efficient at harnessing the energy from moving water as are turbines or revolving blades using the lift principle; however the proposed application is seen as appropriate. The second element is the use of recently developed, variable speed, electricity generation equipment. This is attached either directly to the wheel or via a simple gearing-up mechanism. The third element is the use of existing electronic controllers, appropriate for small-scale machines, to regulate the power output from variable water flow.

Suitability: The proposal is appropriate given the relatively low cost of individual generation stations. The civil construction is small-scale and the manufacture of the paddlewheel is envisioned to be carried out locally. The technology is currently available, although adaptations may be required.

Further Research and Development: Work needs to be done on civil design to maximise the very low head differences. Current flume knowledge may be a suitable starting point. Paddlewheel design needs development, once again, because of the very low head differences, though a wealth of historical knowledge exits. Work is also required to relate paddlewheel outputs with electricity generators and the controller. The scale of electrical output then has to be matched against potential demand.

2. Medium head tidal movement:

The most favourable locations for tidal power application of this type are on the eastern side of the delta region, such as Sandwip. The height tidal ranges occur at the following tidal measurement stations:

BIWTA Gauge No 32 : Satalkhal - Sandwip
Mean Spring Range = 6.01 M
MPA Gauge No 2 : Khal No 10
Mean Spring Range = 4.81 M
BIWTA Gauge No 31 : Sadarghat
Mean Spring Range = 4.72 M

The kind of engineering required given increasing sea levels (due to greenhouse warming) can, under this scenario, be adapted for use as a renewable technology for the future.

The environmental issues in the area need to be assessed but the coast is already heavily engineered for control of flooding and also for fish farming and rice cultivation. It is hoped that the project will provide an integrated approach to island development where the tidal power outcome is part of a bigger concept involving aquaculture and water management. This is a powerful motivation for developing tidal power as it promises sustainable energy for Bangladesh. Box-1 explains how tidal power of Sandwip could be produced for sustainable coastal development in an isolated remote island in Bangladesh.

Potential for Utilization of Energy in Coastal Bangladesh

The coastal environment is an area where terrestrial and marine environments interact to form unique environmental conditions including inshore waters, intertidal areas and extensive tracts of land. Although the coastal environment is an interface between land and sea, the area of real concern is that region where human activities are interlinked with both land and marine environments. This area has been defined as the **coastal resource system**. This resource system can be used in a sustainable way, if the supply of electricity can be ensured.

There is great potential to set up industries and other income generating activities in the coastal region if electricity, can be assured. For example, shrimp farming in the coastal areas of Bangladesh has expanded extensively with the increasing demand from the international market. There is a rapid increase in land use for shrimp farming; in 1983~84 about 40,835 ha, 1985~86 about 68,000 ha and 1990 about 96,048 ha land. The total number of brackish water shrimp farms in 1992~93 was 6540 with an average pond area of 16.5 ha and total land area in 1994 under cultivation of *Peneaus monodon* was 1,35,000 ha. as shrimp ponds, locally called Gher.

Box-1; Decentralised Tidal Power in Sandwip, Bangladesh.

The tides in Sandwip demonstrate roughly a 5 hour 'in' and 7 hour 'out' cycle. Traditional tidal technology would generate large quantities of energy during approximately 6 hours of this cycle. Flow driven tidal technology has the capacity to generate far less power, but over a greater time period.

Utilising paddle wheel technology, and by lagging the flow by 1-2 hours, through the restriction of both in-flow and out-flow, enables generation for approximately 11 hours, of a 12 hour cycle. Here generation occurs when the water is flowing both in and out, with the change in rotation occurring during a flowing tide. Therefore, the static state of high tide is still characterised by subsequent flow through the sluice gate leading to power generation

The inconvenience of the loss of electricity experienced when the turbines are in a stalled state will be diminished through the grid connection of a series of power generators around the island. The differentiation in the timing of tidal extremes (due to tidal currents) around the island should ensure 24 hour power supply.

The integration of electronic controls on the generators can enable these variations in power to be phased in, and regulated into the grid. During the night the excess power produced can be directed into battery charging. These batteries can be provided for households living off the grid. Backup diesel generation can be used to supplement the power supply at peak demand times.

The installation of 75 KW turbines, generating 80% of full capacity for 23 hours per day, equates to the production of approximately 1,380 Kw.hr per day. It is proposed that the manufacture and installation costs for one site will be in the order of $50,000. [By means of rough comparison the purchase and installation of a 75 kW diesel generator is (AUS)$ 37,500. Assuming a running cost of 10 c/kW the annual costs is (AUS)$ 65,700. The capitalised development cost over a 10 year period equates to (AUS)$ 650,000].

With the availability of electricity, it will also improve tourism, prevent green house gas emissions (clean development mechanisms, CDM) and develop an integrated plans for coastal zone management such as integration of modern aquaculture, livestocks, water resource and agriculture management with community development (fig.1).

Project Funding:

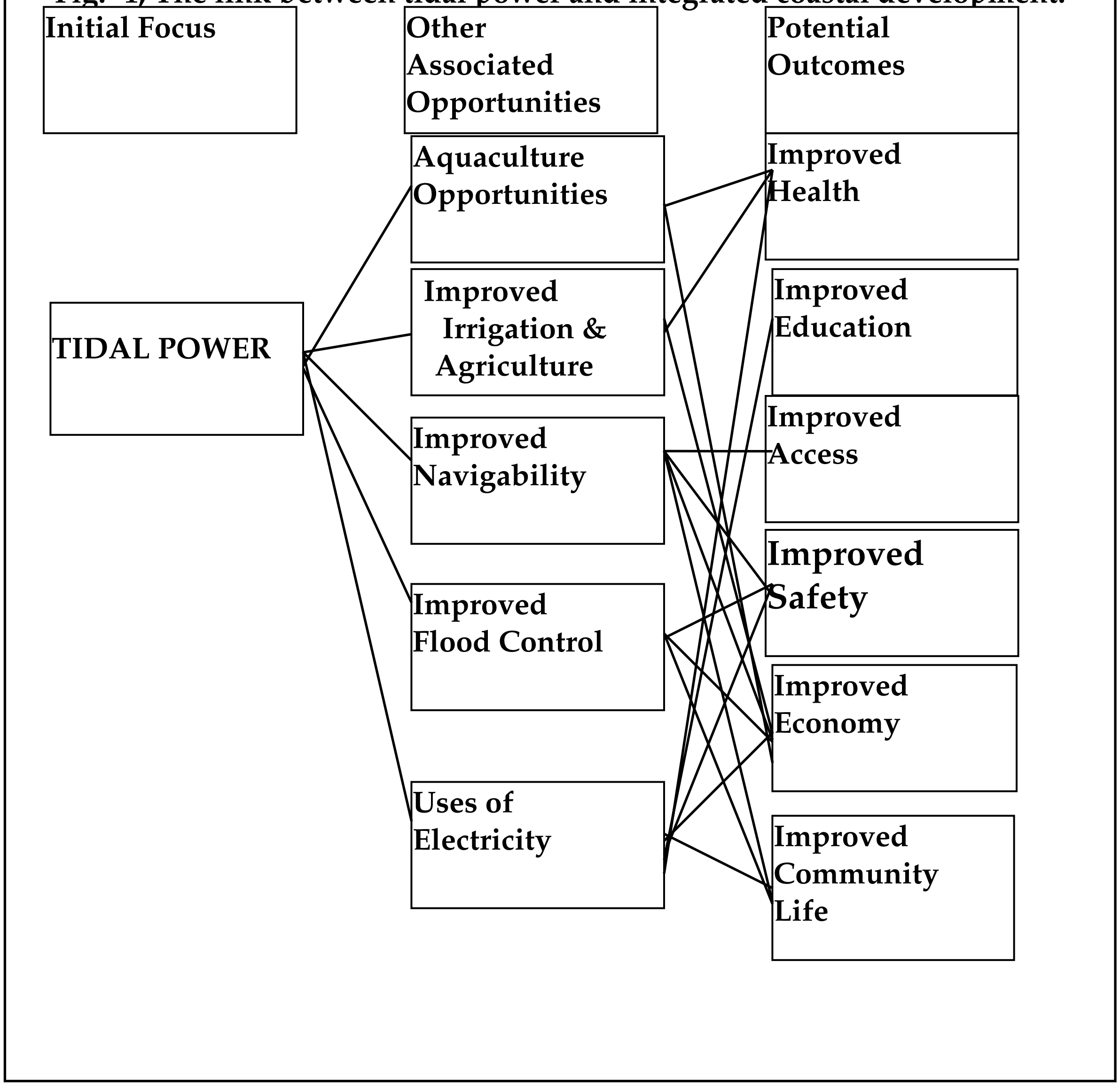
Funding for this project includes a mix of donor aidmoney (Phase I – pre-feasibility study of pilot project), mixed credit with private sector contribution (Phase II - pilot project implementation) and soft loans (community capacity building activities). The prospective sources for financial assistance include the following:

- Funding for the prefeasibility study of pilot project is being sought from UNDP-Bangladesh, ESCAP, and AusAID.
- Funding for the Renewable Energy Pilot Project is being sought from the Australian Government through the International Greenhouse Partnerships program.
- Funding for Community Capacity Building and Institutional Strengthening Activities is sought from the private sector, local NGO's and relevant GOB agencies.

CONCLUSIONS

In a society with increasing energy demand and decreasing supplies, we must look to the future and develop our best potential renewable resources. Tidal power fits the bill as a natural source of energy with many benefits. When developed, tidal power could be a primary provider for our future energy requirements. In this paper, ‘Tidal Power and Coastal Development Program’ is discussed as a worthwhile project, featuring both technical and social innovativeness. Technically, it can be the world's first project utilizing an island’s flood control system to generate small-scale tidal power and developing local aquaculture management. Socially, it will be a model of local capacity building, with Sandwip's socio-economic advancement.

Fig. -1; The link between tidal power and integrated coastal development.



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