Hydroelectricity on Wings of Transition

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Resumo:

A hidroeletricidade é um produto no qual ciência e tecnologia convergem para formar um sistema funcional. Em seus 130 anos a hidroeletricidade alcançou o nível de 20% na matriz mundial de geração de eletricidade. Mudanças tecnológicas e expansão da dependência energética conduziram o setor a opções para alargar a sua base de recursos de poder hidroelétrico. A tecnologia Padrão de barragens permanecerá como um grande setor do sistema A atenção para os sistemas atuais terá o seu papel, elevando o grau das unidades já instaladas. No entanto, outro passo será o desenvolvimento das bacias de marés, como a de La Rence, na França (1966), ou a de Severn, no SO do Reino Unido. Rios de planície atrairão turbinas borbulhantes, onde as barragens terão apenas 15 a 20 metros de altura, para formar leitos inundáveis, em vez de reservatórios maciços e requerentes de reassentamentos extensivos.

Os novos sistemas abririam o Orenoco, o Amazonas e o Paraná para instalações hidroelétricas sem a construção de grandes barragens. Assim, o futuro da hidroeletricidade corresponderia às necessidades ambientais do século 21: mínimo de stress ambiental e custos mais baixos. A hidroeletricidade do futuro vai ao encontro da estabilidade ambiental, e da sustentabilidade no contexto terrestre. Outro passo futuro será a penetração nos mares abertos e capturar a ação das ondas, utilizando sistemas hidrocinéticos adaptáveis. As necessidades mundiais de energia continuam crescendo, fazendo crescer também a necessidade de conservação de energia, através de melhoramentos significativos- de conservação – em usos de energia mecânica, através de melhoramentos nos equipamentos, em todos os níveis. Sendo a hidroeletricidade um componente crescente e proeminente da “rede de poder”, como agem os Estados mundiais para compatibilizar necessidades econômicas, ambientais e societais, e preferências?

Palavras-Chave: Hidroeletricidade. Energia de marés. Energia de ondas. Transições hidroelétrocas. Dependência tecnológica. Conservação.

ABSTRACT

Hydroelectricity is the product of where science and technology converge to form a functional system. Through a 130 year corridor hydroelectricity has reached a 20% electricity generation level in the world energy matrix. Changes in technology and expansion in energy dependence provide the sector options to enlarge the hydropower resource base. Standard dam technology will remain a big sector in the hydroelectric system. Attention to existing systems will have its role in upgrading installed units. Another step in the sector will be the coming harnessing of tidal basins, such as La Rance (1966, France), or the Severn in S.W. U.K. Lowland rivers will attract bulbar turbines where the dams will be 15 to 20 meters high on the order of flood plain inundation instead of a massive reservoir extensive resettlement requirements. New systems would open the Orinoco, Amazon, and Parana to damless hydropower installations. Hence, the future of hydroelectricity would correspond to the environmental needs of the 21st century, minimal environmental stress and low cost energy. Hydroelectricity of the future furthers environmental stability and sustainability in the terrestrial context. A next step would be entering the open seas and capture wave action with adaptive hydrokinetic systems. While the world's energy needs continue to grow, there arises the need for energy conservation via significant improvements – conservation – in mechanical energy uses, improved equipment at all levels. Hydroelectricity is an increasingly prominent component in the "network of power", how do the world's states reconcile the economic-environmental-societal needs and preferences?

Key Words: Hydroelectricity, Tidal Power, Wave Power, Hydrokinetic, Transitions, Technology Dependence, Conservation.

"Any real problem must surely lie generations ahead; let them worry. It is against this sort of background that we must judge the prodigal use of energy that characterized the early decades of this century, most particularly in the United States with its immense resources, but with other Western nations lagging behind not for any reason of prudence, because they could not afford it. Of the two embarrassing legacies that have been left to us by the technology of the first half of the twentieth century- the problems of the environment and of maintaining adequate energy supplies – it is the second that is the most pressing and will tax the resources of the technologists – and the politicians – of the remaining years of this century and the years beyond."

T. Williams,(1978) "Technology and the quality of life", in A HISTORY OF TECHNOLOGY, vol VII, T. Williams, ed., p.1482. New York, Oxford U.P.

1 - Hydroelectricity on Wings of Transition

Impermanence is inherent in dynamic systems. Energy is a multifaceted force, hence changes, transitions in stages, is a functional characteristic imbedded in its articulation. Energy as a term enters the English language in 1599. By 2010 it shares with its multiple sources the world stage with water and food to sustain politically – economically organized state systems. Within the energy matrix, electricity has increasingly occupied a more prominent position. When Michael Faraday illustrated his invention by 1832 to P.M. Peel, the latter wondered about its utility, to which the ex-book binder responded, that if electricity generates cash, those with political power will discover a way to tax it (Hirshfeld, 2006, 123). Advances in electro-mechanical technology changed locational options, the standard of life, industrial systems and communication systems. In time electricity generation systems branched into thermally powered and hydro powered installations. As the demand for electricity rises globally, transitions to more universally accessible physical resources fosters resort to technologically clean and environmentally benign mechanisms. As Williams wisely notes in the above quote, it is time to shift from physical resource dependence to clean technical applications.

The move from hydroelectric power to hydrokinetic power is on its way. Its pace will be influenced by the interest groups that orchestrate the intellectual orientation of the technology that is in its formative stages and decision makers that define the given time-frames. As systems grow in technical complexity, budgetary foci shift from resource base costs to human resource costs – intellectual property costs and professional expenditure placed in uncharted terrain. The future is an unknown place, hence electricity planning has to include scaling to afford collision-free passing of unanticipated bottlenecks.

2 - Orientation of Study – Purpose

Environmental study, its history, (Thomas, Jr, MAN'S ROLE, 1956, Glacken, TRACES, 1967) readily identifies the limitation to the possible and provides the essential markers and bound parameters for a viable electricity generating system based on hydro resources. Originally river-based, in the 21st century technological changes will gradually enter the large open water bodies, tapping into tidal systems as these tend to be coastal in location (Figures 1 and 2). This experience can be expected to foster Wave technology, which dates at least to 1945, first applied to buoy lighting. In 2010 an altered scale change will create a dimension of generating infrastructure that depends upon the investment scale in the wave generating systems.

Established hydroelectric systems afford predictable generating schedules at specific dam sites (Figure 3). Hydroelectric engineering observes local norms with fidelity; about the only thing beyond the reach of engineering control is incidence of precipitation in specific project water sheds. Most projects anticipate to generate at an annual average of 50% to 57% of installed nameplate capacity of a dam. When the shift is to hydrokinetic power, one has to include the absence of reservoirs, hence the evolving hydrokinetic system solves physical-social problems, but stands disarmed versus stream flow oscillations. This presents questions, where to place hydro kinetic installations, what stream flow minimum is required for such a novel system? To what extent would a hydrokinetic system fit into the Rhine, Danube, Mississippi, Orinoco, or Amazon? What is the dependability status of hydrokinetic versus hydroelectric electricity generation? In the age of communication dependability, electricity availability approaches the need for breathing with regularity.

3 - Hydroelectricity in the Expanding Energy Matrix.

World-wide hydroelectricity constitutes about 20% of all electricity generated globally. There are local fluctuations indicative of regional variations in annual precipitation volume and generation totals. World-wide there are significant shifts in regional electricity matrixes as individual countries cope actively with increasing electricity demand in all sectors of the economy, transportation, and communication, to cite the more prominent examples. The absence of uniformity in the hydro sector disallows sweeping generalities. Furthermore, the hydro sector is a multi-purpose sector which serves foremost agriculture, as 40% of the world's food staples are produced on irrigated land watered with stored water. Most of the world's urban system is river-water dependent. These include numerous large rivers that no longer shed water into the open sea as the Indus, or the Yellow River, or the Nile, and attention to water competition comes into focus. For a time hydroelectricity served as a symbol of change, now it is used as a mark of environmental dislocation. Nearly everywhere, hydroelectricity has acted as positive electricity provider from bio or fossil fuels in a clean energy transition. In the process it significantly reduced the ghost acreage syndrome. (Bergstrom, HUMAN PLANET, 1972)

Anticipating the future, it is time to address the issue of how to phase in hydrokinetic energy with hydroelectric systems. This is partly a transmission system, partly a placement of the mechanical installations. The transmission system is a technical condition which is readily amenable to technological solution. The placement of the hydrokinetic unit within river systems in conditioned by stream volume and velocity. Engineers may devise a hydrokinetic system that captures turbined water from the hydro electric unit, as well as the excess water released by the spillway gates. This would enhance total water use, notably increasing electricity generation. Both systems can effectively expand concurrently. Illustrated here is the physical design of a model hydrokinetic model_possibility of using the excess generating installed capacity for hydrogen production (Figure 4). The latter would open the way for hydrogen use foremost in aviation – clean energy instead of fossil fuels.

4 - Hydroelectricity- Growing Energy Needs and Environmental Conditions.

With few exceptions installed hydroelectric capacity cannot meet market demand generation. Exceptional states are Norway and Paraguay, to which Bhutan can be added, and Laos may be included in the near future. Electricity consumption outpaces generation as a consequence of changes in electricity dependence in its multiple forms of individual usage, and the increased mechanization of the manufacturing process, notably robotization, the metallurgical sector (foremost Aluminum, with about 15.6 MW/ton), rail transportation, refrigeration, and the varied communication systems. Growing electricity demand and dependence upon it are the sum of the convergence of multiple independent users who plug in but are unconnected with electricity planning and policy. And since electricity is generally identified as a clean energy source, individual environmental qualms tend to be low level.

Electricity market research peers twenty years into the future, anticipating electricity demand. Most consumption projections are built upon past consumption behavior, which includes such novel energy guzzlers as microwaves, flat-screen T.V.'s, computers, air conditioning, and other novelties in the works. In an emergency, a used jet engine could be installed within two days if the transmission system is in place. A mere consideration of the spatial complexity of the electricity delivery system could show the impulsive haste. Now add construction of a hydroelectric complex, and the time horizon for the project tends to span ten to twenty years. By the time said project enters service, the original electricity market projection may have been superseded by multiple demographic, industrial, and economic shifts that form independent vectors in socio-economic systems. Hydroelectric systems have to be linked into the environment, this obliges for comprehensive analysis to anticipate the physical impact such a project has locally as well as regionally – this is the 21st century, not the 1930, Hoover Dam epoch.

With environmental awareness being an active component in project planning, minimization of project environmental impact has become an effective component of the project planning and implementation process. It is at this point where new technology promotes resource use without causing environmental dislocation. Hence, instead of an extractive resource use, technology introduces resource use without resource use, namely a passive resource use, in this instance hydrokinetic, or installing run-of-the-river turbines, damless, weirless, use of the water. To install such system requires detailed stream flow data to anticipate generating dependability. To this end numerous climatic data have to be assessed for such watersheds, especially the km2/km3 ratio (Figure 5) to project water availability within a watershed to plan within a parameter of predictability. There are multiple options, good examples could be the Paraná River from Resistencia to Zarate, Argentina, the Amazon from Tabatinga to Macapa, Brazil, or much of the Orinoco River Venezuela. Hence, these major rivers could serve as complementary hydro energy laboratories before entering smaller river basins with hydrokinetic installations. (See Figure 4)

5 - The Changing Pace of Technological Change: From Buoy to Localized Electricity Systems

To observe the pace of technological change through the corridor of time affords perspective and allows reflection (Figure 6). The graph shows transitions and energy source expansion. To be in the current of technological change is personal and the resulting analysis may suffer the sting of the moment. Reference may be from the Atari computer to the Apple "iPad" – the latest in communications technology. Electricity and its generating system passed numerous transition phases (Figure 6), from hydro to nuclear and numerous intervening additions, including wind and solar as powering electricity sources. The pace of change is demand, market, and price conditioned. To this has to be added resource base availability, and an accessible distribution network. Electricity initially had a distribution field measured in 1km, today 3000 kmt are part of transmission technology. (Figure 7) Furthermore, transmission has to be environment adapted, underground in urban settings, underwater in river crossings and open seas, or in very cold or very high temperature environments.

Technological change will be influenced in significant part by environmental needs. Rise in electricity demand will influence technology to depend increasingly upon the least polluting energy sources, such as solar, water, and wind. Attention here is upon the world's water resources. As the 2002-2010 report and research inventory from Hydro power and Dams indicates (Table 1) there has been a notable rise in research and application in the mechanization of water in the generation of electricity. Tidewater studies and installations lead at the moment, and the more novel entrant Hydro-kinetic is entering the prototype phase (See Table 1). From idea to market is one step, but to shift from thermal to hydrokinetic electricity opens the path for a reshaping the "networks of power." The time frame that has to be factored into such a system as it is shaped by the volume in question – the longer it takes to move such projects on line, the greater the time loss to bring new systems on line. New infrastructure costs, costs for the kWh produced, the obsolete infrastructure write downs, and all the variables contribute to reshape the electricity supply system.

In time perspective it is wise to consider the emerging transitions in phases measured by decades. Eventual successful creation of the electromechanical infrastructure will be marked by the creation of least cost per kWh generators and minimal maintenance time and costs. Hydroelectric projects provide functional and economic perspective in this transition, as these until the present produce the lowest cost electricity world-wide. Alternatives to dams such as Caissons -installed as individual units instead of a closed barrier as dam or hydrokinetic turbines placed into river currents alter structural morphology, environmental modifications, lowers structural investment and eliminates population dislocation. Project magnitude will register notable change as projects may be operated with large numbers of standard sized generating systems. An assembly of 100 generating units at 50 MW or a 5 GW complex would differ significantly from a 5 GW hydroelectric entity. Construction time would be very different, a less transitory labor force, but a significantly larger operator crew would need to monitor operations. General design and operation of the electromechanical equipment could be standardized, simplifying mass production and lowering investment outlays.

6 - From Rivers into Tidal Basins

Change in technology opens opportunities previously inaccessible. One of the first operational models is the La Rance project on the Normandy coast, France (Figure 8). It is a tidal flow basin with 24 turbines that power 10 MW generators. Tidal basins identify the global belts with the most favorable potential generating conditions (Figure 9). The identified tidal basin sites serve to enlarge the accessible hydro resource base. Moreover, the local river hydro resource base is correspondingly enlarged, and the once unthinkable turns into the feasible (figure 10)(Russia). At this time the Russian engineers drawing upon decades of experimentation that is coming to fruition as numerous studies illustrate in an extra issue of HYDROPOWER AND DAMS, supplement, December, 2009. Among the leading hydro engineers, F. Lemperiere, provides a survey titled “An Overview Of Tidal Power Potential and Prospects”. In this review the author considers potential, market, and environmental aspects of electricity generation. Globally the tidal potential is comparable to that of the world’s river systems (this does not include the coming hydrokinetic potential of the world’s rivers) Lemperiere identifies the current world electricity need at 20,000 TWh/year, which is projected to reach 50,000 TWh/year by 2040 (Lemperiere, 2009).

Lemperiere is attentive to energy transitions, and he considers increases in fossil fuel consumption into 2020, but this to decline to less than 10,000 TWh/year by 2040. That spells a notable shift to other energy sources, hence increased dependence for electricity upon added hydro resources. This is in good part in response to climate change. Nuclear power in these calculations is expected to peak globally at 5,000 TW/year by 2040. (Uranium is a mineral and limited in availability as currently known). The maximum total electricity generation from hydroelectricity, geothermal and biomass are expected to peak at 10,000 TWh/year in 2040.

Prospects according to these calculations will place half the electricity generation into the solar and eolian sectors and here the issue of kWh costs surfaces. Minimal projected cost is $ 0.05/kWh, but $0.10/kWh is a more realistic cost estimate. This cost comparison with hydroelectric per kWh of $0.02 speaks for itself, but at this point to suggest the cost of hydrokinetic electricity is tenuous. The cost factor gains in this electricity generating system as the quantity of electricity stands to increase and that spells notable increases in infrastructure investments. The environmental costs and the conventional patterns of the transmission as part of the system have to be considered. Tidal and hydrokinetic electricity may significantly hasten reduction of fossil fuel dependence, but large river investments introduce capital burden that have to be included in projected electricity costs.

Hydroelectric and hydrokinetic so far are river bound, hence function in fresh water bodies. Tidal systems and evolving wave action equipment will be exposed to chemically corrosive water bodies. Ceramic or glass offer a partial answer to these challenging environmental vectors. Another option for the turbines may be found in stainless steel to enhance resistance to water-caused corrosion and pitting caused by water and sediment cavitations.

Hydroelectricity is powered by gravity and compression. Tidal power is turbine activation on the basis of mass and pressure. In the case of hydrokinetic electricity the turbine is powered by the horizontal unobstructed flowing of a discharging river system, rotating the runner (turbine) to activate the rotor mounted on a vertical axel. Engineers will devise transmission –gear- systems to produce needed acceleration in the rotor to enhance electricity output in the system. To move from prototype to generating unit, to achieve economy of scale engages much engineering talent and the effective combination of materials that stay in service for several decades. In the hydroelectric sector a generating unit is expected to be in continuous operation for at least 17,520 hours (2 years) before being idled for a technical inspection, which takes two weeks for large generating turbines, 350 MW@; After 87,600 hours (10 years) the unit may be completely disassembled and replace defective parts or the entire generating unit, depending upon the wear of the entity. With the simplification of the electromechanical infrastructure to project a maintenance cycle for this different equipment has to be provided, but cannot be predicted now. It should be noted, that scale of installation and equipment will change as production norms gain in regularity and improvement in operation introduce production predictability and dependability. The pace of change, the transition phase initially will be in the realm of engineering, but once it becomes a condition of scale and costs, political considerations have to be factored into the electricity planning process to effectively schedule the local transition phases.

7 - Run-Of-The-River to Hydrokinetic and Wave Power

As noted above, hydrokinetic has not attracted to date comparable effort that tidal or wave projects have mobilized. With the hydroelectric infrastructure established and predictable once on line, the technical change requires change in operation and maintenance. Moreover, the tidal basin includes massive projects which have the potential to turn into major electricity generating sources. To this end the Russians developed standardized runners (Figure 11) The hydrokinetic system on the other hand offers an opportunity previously non-existent – namely to use dependable water sources for multiple uses and eliminate large dam projects at high costs, without land loss, forced resettlements, and long construction periods. Furthermore, the installation of hydrokinetic equipment could be compared to building a rail line. It would be programmed, and the turbine and rotor could be built to river volume specification. Hydrokinetic electricity is a form of modernization of capturing an open river's electricity potential.

Rivers that were not used for electricity generation, or could not be dammed and those that are damned, all of these can be included in the hydrokinetic potential. Rivers that flow into irrigation systems can be included in the hydrokinetic potential inventory. Undammed rivers such as the Amazon with hydrokinetic turbines could turn into an enormous electricity source, virtually unmatchable anywhere. Furthermore, hydrokinetic installation can be placed between dams. The damless technology would greatly reduce electricity base cost and advance the standard of life, reduce dislocation and enhance environmental conservation. A collateral advantage of the hydrokinetic system is that the natural sedimentation process of floodplains and the river geomorphology would be at most little effected and much of the floodplain for agricultural land uses would remain available.

The amount of electricity the hydrokinetic turbine can deliver at this phase of its technological creation is an incognito. From prototype to major generating entity may take decades, this depends in great part upon how ‘the network of power’ wants to shape its future. In the Amazon one can mount one size unit, in the lower Hudson another scale model would be appropriate. Answers to these concerns should be observed experience based. In 1961 the American people were informed that within ten years a person would be landed on the moon, well they got there in eight. It all depends upon the urgency with which the subject is pursued and brought to completion.

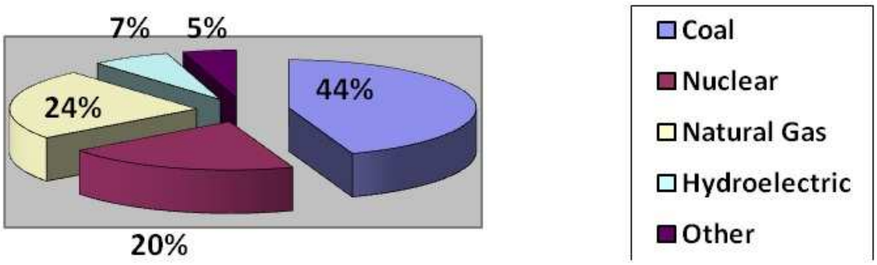
Wave action is another hydro means to transform water movement into electricity. Wave action has a notable history, in the case of tidal control first mention gives to a study by Boibner (1921) *THE USE OF TIDAL POWER*, the wave action was first effectively harnessed for electricity by a Japanese engineer for application in lighting sea-buoys (1945). Sea buoys carried carbide lamps that needed to be refueled; the bobbing buoy with its wave action device became a self generating lighting system. Wave action in a way is a step into the open water bodies. First efforts serve to harness on-shore waves and capture the wave energy in basins while draining the water with the help of the turbine. Shoreline proximity is favored to reduce transmission line distance (the cost factor). These efforts have attracted attention and considerable effort from Australia to the UK, the US, Japan, China, and Norway to cite a few cases. It is a matter of time, but in the end it will be the world’s oceans and the sun that will change our energy dependence to clean and free energy, from fossil and bio-fuels.

One way to assess the coming changes is by tracking the research activities in the various hydro-use sectors in pursuit of electricity generation. A review for eight years of Hydropower and Dams (2002 – 2010) reveals a notable increase in Wave Action Studies, and application, Tidal studies and instrumentation systems, and growing attraction to hydrokinetic research and application (see Table 1). The emergence of the topic reflects the laggard general human behavior. Tidal wave studies can be traced back to at least 1921; the Russians have been active in the tidal study systems since 1938, and the Japanese – British since the 1940's in open water waves. This takes us back to an elementary condition – what is the resource base your 'network of power' depends upon? Limited resources inspire to seek expansion of the energy resource base by any means accessible, either physical or intellectual. The global system has reached a status where a shift from the physical resource base to the human-intellectual-technical has become environmentally and socially unavoidable.

8 - Technological Resources - Enlarging their Sphere in Electricity Generation

Environmental and economic considerations converge. In the past it was the economic domain that set the pace in the energy-electricity domain (Hughes, Networks, 1983). Much of the energy delivery is managed by large firms, such as Esso, Consolidated Edison, YPF, Epsol, Total, B.P., Suncor, Gasprom, Petrobras, Aramco, ENI, these samples serve to afford a limited view of the global condition. It may provide some context to cite select US data. Energy data collection tends to be laggard as it is massive, the data supplier show no haste to provide the information. All data cited are for the U.S., these are select and only provide a limited number of inference points. The US electricity mosaic for 2008-9 was comprised of these components:

Figure 11 – Key US Electricity Sources



The 2006 data provide this perspective: GDP $\$13.345X10^{12}$ and 1.157/13.345 for energy which = 8.7%. All commercial Energy sales were $\$1.157X10^{12}$

And in 2006 retail electricity sales were valued at 323,865,000,000 or 27.9% of all energy costs, or 2.4% of GDP. This historic data affords one way to assess the role of electricity in a particular system. While the data is limited, several considerations command special attention. In the electricity bill, the geothermal, hydro, eolian and solar energy are free, in such global analysis it is ignored. As the move is to reduce fossil fuel dependence, and nuclear is limited, how is the energy cost going to be determined as society becomes hydro-source energy serviced? How much conservation incentive can be incorporated into future electricity rates? What and where can engineering gains be placed to achieve notable reductions in electricity consumption?

9 - The coming changes in Hydro Energy Generation, Expenditure Shifts and Possible Economies, Including Changed Environmental Properties.

Transitions tend to be uneven in time frame, in consequences, and economic outcomes. Transitions in the hydro sector depend upon the creative pace and impact associated with the engineering and technology sectors. Introduction of changes in technology and their acceptance varies with the economic consequences of the shift in energy generation. Any change in public service or public product includes moving from the known to an unproven service system, which includes displacement of an existing service, hence obsolescence, or additional expenditures need to be considered as a constraint on ready innovation diffusion. This condition can be expected to gain prominence as the global energy sectors gradually move toward significantly reduced fossil fuel dependence. A combination of novel non-fossil fuel energy systems and additional energy technologies will further conservation measures and reduction in environmental impacts throughout.

Most of the changes will be located in the renewable energy sector, and here the solar and hydro sectors offer the longest, cleanest, and most accessible resource base. The eolian source and the geothermal sector will contribute importantly to the global energy matrix. The hydro sector will gain as the generating technology will simplify tidal exploitation, master ocean wave use for electricity generation, and as hydrokinetic energy makes dam less systems the norm. As renewable systems come on line, the economic consequences draw attention. Institutional changes are generally accompanied by political, technological, economic, and cultural tensions. The political considerations tend to reveal the particular interest groups which turn nervous as their territorial security is threatened by the changes in available energy sources. The hydro sector bears no resource expenditure, as rivers do not charge, tidal waves are free, and the wind liberally activates the ocean waves. Infrastructure expenditures are part of energy production. The absence of a coal bill or gas account, that changes the economy of energy generation. How this will impact budgets of energy consumers is beyond prediction, but there will be multiple savings. How this will be managed on the global scale is beyond the objective here, but attention to the topic will emerge.

The energy cost factor shapes projects, as the price per kWh influences policy makers-planners, and political decision makers. Fossil fuels prior to exploitation have to be located via exploration. This is followed by extraction, generally transportation, refinement, and distribution. Each phase has its price, which the user has to meet if the product is wanted. A similar approach applies to coal, uranium, and gas; these are base costs that end users have to accept. How much economy could be achieved as economies separate themselves from fossil fuels?

As the world economy reduces its fossil fuel dependence, how does increased hydro energy dependence influence economies? Until this time water use in hydroelectric systems has been a free resource. Fossil fuel elimination has numerous collateral effects, as it would spell the end of massive transport systems, greatly reduces exploration costs for exhaustible resources, notably reduced refining, and lowered employment in the sector. To put this complex energy system in some perspective, the next lines provide a view of the US G.D.P. for the energy sector nearly 40 years assessment. By referring to the US GDP, the total economic activities and the respective values for the multiple sections of the system are summed. Energy forms an integral part of the country's GDP, hence two data can be evaluated to record the GDP and energy sector relationship for select years; in this case 1970 to 2006 provide an idea of how much it costs the U.S. economy in energy expenditures in given years.

Table 3 – US GDP and Energy Expenditures

Year	GDP(10^9)	Consolidated Expenditures For Energy 10^6	GDP/CEE %
1970	$1,038.5	$82,911	7.98
1980	$2,789.5	$427,140	15.3
1990	$5,803.1	$472,030	8.13
2000	$9,877	$688,774	7
2006	$13,000	$1,157,910	8.9

The GDP advanced about 12 fold between 1970 & 2006, while energy expenditures advanced about 14 times in the corresponding time frame. 1980 marks the year when the oil price change became prominent. At this time, 2008/9, the US spends about 8.7% of its GDP on energy of all kinds at the various functional levels. The available data tables make no reference to the military and its energy consumption. On the other hand, an American Airline pilot stated that AA uses

.3% of the US petroleum market. As energy dependence shifts to hydro, the GDP/CEE ratio would economically turn more positive for the US.

The coming changes in the hydro energy sector will contribute to environmental conservation at multiple levels. The gradual decline in fossil use globally will consume much time, but the consequences will emerge and turn visible once the CO_2 values turn stable, at that point the turning point is reached. This condition varies from country to country, as the energy matrixes reflect the country's particular energy mix. In the shift from hydroelectric to hydrokinetic energy greater attention to river water monitoring in quantity and quality will be necessary for dependable electricity generation. Cost reductions in fossil fuel expenditures faces government environmental outlays. At the same time a shrinking in the fossil fuel taxes has to be included in the transition in the total energy sector.

If wave action electricity can be transformed into hydrogen, this process could be installed on platforms in the open seas and thereby reduce distance transmission of electricity. This would be a pollution-free hydrogen industry that could power water and aircraft. For the atmosphere that would be a significant reduction in air pollution and curb particle concentration in the atmosphere's circulation belts. In maritime transport fossil fuel fumes and oil spills could be gradually eliminated, significantly enhancing the oceanic biosphere. The implicit technological transition depends upon an extended time frame which will be uneven on the world stage. Leadership rests with the technological centers, which will also free these from energy dependence, hence these technological centers tend to welcome the opportunity to regain energy autonomy and improved geopolitical sway and power. From prototype to global system has to be placed in a 30 to 70 year span. Even if the technology comes into existence, what are the costs of such transition and how many countries can master the finances to benefit from this shift in energy kind?

Discussions about energy transition generally focus on how to power the car. This comes into focus in "Fuel of the Future", (Nature, 464, 1263-5). Tollefson affords a succinct overview of how the "networks of power" anticipate the future. Competing interests in 2009 moved swiftly to scuttle the token President Bush hydrogen effort and put bio-fuels and batteries in first place. With hydrogen down and bio-fuels up, a change in priorities appeared in place. In the meantime, the key car manufacturers united to further the hydrogen fuel cell car development. This illustrates how the “network of power” works, government on one side, manufacturers on the other. It reveals the influence of politics, economies, and culture in clear outline. More-over, it is a clear geopolitical divide, Europe pro-hydrogen, the US (Dr. Chu, Secretary of Energy) promoting bio-fuels as these are more immediately accessible. To this needs to be added previously cited fossil fuel infrastructure obsolescence and the projected need for 11,000 hydrogen fueling stations just for the US. It should be noted, a hydrogen fueled car has proven its autonomy of 653 km (405 miles), in Brazil an electri-car has reached autonomy for 150 km (93 miles), illustrating the technology available in 2009.

The topic will engage many, the outcome is clear – the gasoline engine will join the incandescent lamp in the museum. More importantly will be the energy transition from fossil to renewable – clean energy, above all the accompanying energy conservation and potential reductions in energy costs, and the reduced pressure on the environment and resulting total social economies. Tollefson and Hughes capture how “the network of power” functions. There are no parties to the energy transition; it is a linear technological process that is built upon precedent that is focused upon minimization of energy use and costs. The waves will decide in favor of hydrogen – the ocean waves are free and clean. [1]

With a well based fossil fuel infrastructure in place, its speedy demise constitutes an unrealistic and impractical consideration: To replace the volumes of coal and petroleum in daily global consumption calls for decades of transition in effective replacement planning. Investment requirements in such transitions are of an unfamiliar magnitude. Indicators increasingly point to its approaching inevitability, namely the environmental imperative, as marked by the highest April temperatures ever registered at 58.1^{o} Fahrenheit, the persistent air pollution, and the rising base cost prices of non-renewable coal and petroleum and their derivative products. Mitigating efforts cannot cope with the growth in the volume of daily energy requirements.

China is the premier world coal producer and consumer. “In China, Soaring Energy Appetite Threatens Emission Goals” (Bradsher, 7 May, 10), reporting a 24% increase in the first quarter of 2010 of coal powered electricity, and a similar increase in petroleum consumption. For decades efforts have been made to work with clean coal, like Paracelsus the Alchemist sought to produce gold, to no avail. In the U.S. the idea of sequestration is to clean the air. “A Bad Bet On Carbon” by R. Bryce outlines the costs of this particular effort. (Bryce, 13 May, 2010). There is no clean coal. Bryce’s short article had the Assistant Secretary for Fossil Energy, Department of Energy, respond in a letter to the Editor (NYT, 21 May 2010)” Since the world will continue to rely on fossil fuels for most of its energy in coming decades; C.C.S. (carbon capture and storage) must be part of our energy strategy.” Ms. Obenshain notes that there is ample storage capacity to store the coal emissions. Byron Elton of the Carbon Sciences considers a bet on carbon terrific. This illustrates different viewpoints on the topic.

Petroleum and natural gas are used worldwide, hence these command much attention. “How Shale Gas is Going To Rock the World”, what the author overlooks is that to gain access to the gas the drilling technique is most detrimental to the ground water system and renders it unfit for human consumption. (Jaffe, “How Shale”, 10, May 2010). The B.P. drilling accident in the Gulf of Mexico, 20 April, 2010, serves to illustrate as the pressure for petroleum reserve replacement drilling turns more risky, consequences of malfunctioning gain in severity. In the U.S. there are over $2000X10^9$ barrels of petroleum in oil shale, but to extract it would be environmentally unpalatable.

Currently there is a notable transition in domestic lighting. In the US the incandescent bulb is by law to be replaced by 2012 by fluorescent lights. That is a directed conservation measure. The fixture costs more, has a much longer functional life, but it’s use is 75% less costly than the 1880’s Edison incandescent bulbs. Hence there is a public aspect to the energy transition as well as a private one as characterized by household budgets. These changes are multi-sectoral, which reveal the magnitude of the impending energy source shifts to keep the global system smoothly productive.

The pace of the coming modifications in the global energy system will be influenced by cost considerations, domestic politics, international competition for physical resources, hence the 200 mile limit takes on more overt significance than previously stressed. Each era in the world system adjusts to multiple changes in science, technology, politics, culture and environmental conditions. This includes acceptance of obsolescence in resource use and

While the coal issue is home based, the oil imports are constantly increasing, and in May 2010, U.S. petroleum consumption was about 19,500,000 barrels / day, of which about 5,000,000 barrels are domestically produced, the balance had to be imported. Of the 5,000,000 / day of U.S. produced petroleum, about 33% is Gulf of Mexico produced. This explains growing U.S. dependence on petroleum imports from Canada. Much of Canadian petroleum exports are tar-sand derived, causing significant local pollution risks (Krauss/Rosenthal, “Mired”, 19 May 2010). Hence, much of the environmental impact of U.S. oil dependence is off-shore, or the environmental impact is noted elsewhere. This is the “ghost acreage”, it is there, not here.

As the supply options decrease, available replacements decrease in volume and increase significantly in base costs. The U.S. Chamber of Commerce Energy Policy group has prepared a study, projecting overall energy price advances. S. Eule, a member of the group stated “as the economy recovers, we are showing that energy security gets worse and worse. Among anxiety triggering factors: Department of Energy forecasts that household energy costs will rise 3% a year through 2030; worry that electricity transmission capacity won’t keep pace; and forecasts that crude oil prices will rise sharply as developing markets boost demand.” (White, “Chamber”, 2010).At the same time the environmental constraints gain in public acceptance and the public health sector commands increased environmental regulations, i.e. more controls. As pressure mounts to shift from fossil fuels to renewable energy sources, the role of technology assumes increasing significance and the previous fixes of increased coal and petroleum production prove untenable. A different energy world is emerging; it will be costly and uncomfortable for the transition. Those who consider escape from this process as possible overlook that the condition has turned global in scope rather than remain local. The shift from resource dependence to technology dependence will emerge as a dominant vector in the modified energy system.

10 - Transitions in the Use of Hydro Resources

Technological inventions and modifications continually generate shifts in resource utilization with the objective to achieve improved productivity and economic performance, including improved environmental management. Changes in technology may significantly alter the use of river systems for generating electricity. Those changes in the use of hydro resources for electricity generation are in an early growth phase, which includes tidal systems, wave action along coastlines, the open oceans, and the world's river systems. Many changes will initially be concurrent as the sorting – out process will be directed to identify the most productive and least costly system for very large electricity generating installations. In the process population growth in numbers and urbanization will exert their respective visible and indirect influences.

Among the dominant possibilities, the tidal systems may be the first to register significant acceptance rates once the implementation costs can be kept within a $0.05/kWh rate. Countries favored in this sector are Russia, the UK, Canada, and the U.S. east coast. Wave action is a more complicated technology but with a virtually unlimited resource base. Here costs will be governed by distance. These installations can be termed 'wave action farms' and the transmission networks could be compared to an urban limited access highway system. Hydrokinetic electricity is the third candidate in the triad and contributes to reduce and/or terminate dam construction including reservoirs. (Those who hope for the end of dams only should think of urban water supply systems and irrigation dependence, to recognize the challenges of water management). Once an effective hydro kinetic system has been introduced, scale of operating units will be set by stream flow based on m^3/s. Hydroelectric dams are not obsolete, but change in cost construction and maintenance expenses will change the hydrographic environment and the river systems. How effective this shift in environmental management will be depends upon local environmental policies.

The focus of the options and opportunities opens the vistas for a far more prudent approach to the environment then the most recent history allows. This status is in sharp contrast to the 1972 CARELESS TECHNOLOGY which e.g. reports on Akasombo in Ghana, 1kWh/ha.

The time is at hand to move from resource dependence to intellectual-technical dependence. As electricity turns increasingly hydro based, it also eliminates resource extraction, resource transport, resource waste and resource costs. The future is an unknown place, but it is an unavoidable destination. Knowledge and use of historical geography can contribute to a more effective and to a more constructive harmonious environmental guardianship.

[1] - Fossil fuels comprise an integral part of industrialization, transportation, and the associated standard of life, comfort. It can be traced to the increased acceptance of the steam engine, the invention of blast furnaces for the emerging steel industry, and the evolving rail and steamship systems. When petroleum became part of the energy mix in the 1860's, the fossil fuel culture turned into the dominant energy source for the twentieth century, and extending well into the 21'st century. Artist Klee identified the detrimental environmental impact of coal in his artistic expressions of industrial air pollution around 1910 in the Ruhr industrial region (Germany).

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The NEWS Sections:

(2003) X, 3, 24

(2004) XI, 2, 20

(2005) XII, 4, 18

(2006) XIII, 6, 22; XIII, 6, 26

(2007) XIV, 1, 8; XIV, 3, 18; XIV, 4, 22

(2008) XV, 1, 18; XV, 1, 22; XV, 2, 4;

(2009) XVI, 2, 18; XVI, 2, 18; XVI, 2, 24; XVI, 5, 31; XVI, 6, 6; XVI, 6, 12;

(2010) XVII, 1, 8; XVII, 1, 10; XVII, 1, 12; XVII, 1, 14; XVII, 1, 18; XVII, 2, 27;

GREEN POWER

(2002) IX, 3, 111-2; IX, 3, 114-5;

(2003) X, 2, 149; X, 3, 115; X, 3, 115;

(2004) XI, 2, 131-2; XI, 2, 132-3; XI, 2, 133; XI, 3, 121;

(2005) XII, 2, 159; XII, 2, 162; XII, 3, 108; XII, 4, 99;

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(2007) XIV, 1, 119; XIV, 2, 103-4; XIV, 3, 155; XIV, 4, 104-5; XIV, 4, 105; XIV, 4, 129; XIV, 4, 130; XIV, 2, 104; XIV, 6, 108;

(2008) XV, 1, 132; XV, 2, 140; XV, 4, 99; XV, 4, 100; XV, 4, 102; XV, 5, 155-6; XV, 5, 158; XV, 6, 142; XV, 6, 143; XV, 6, 144;

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(2010) XVII, 1, 92; XVII, 2, 129.

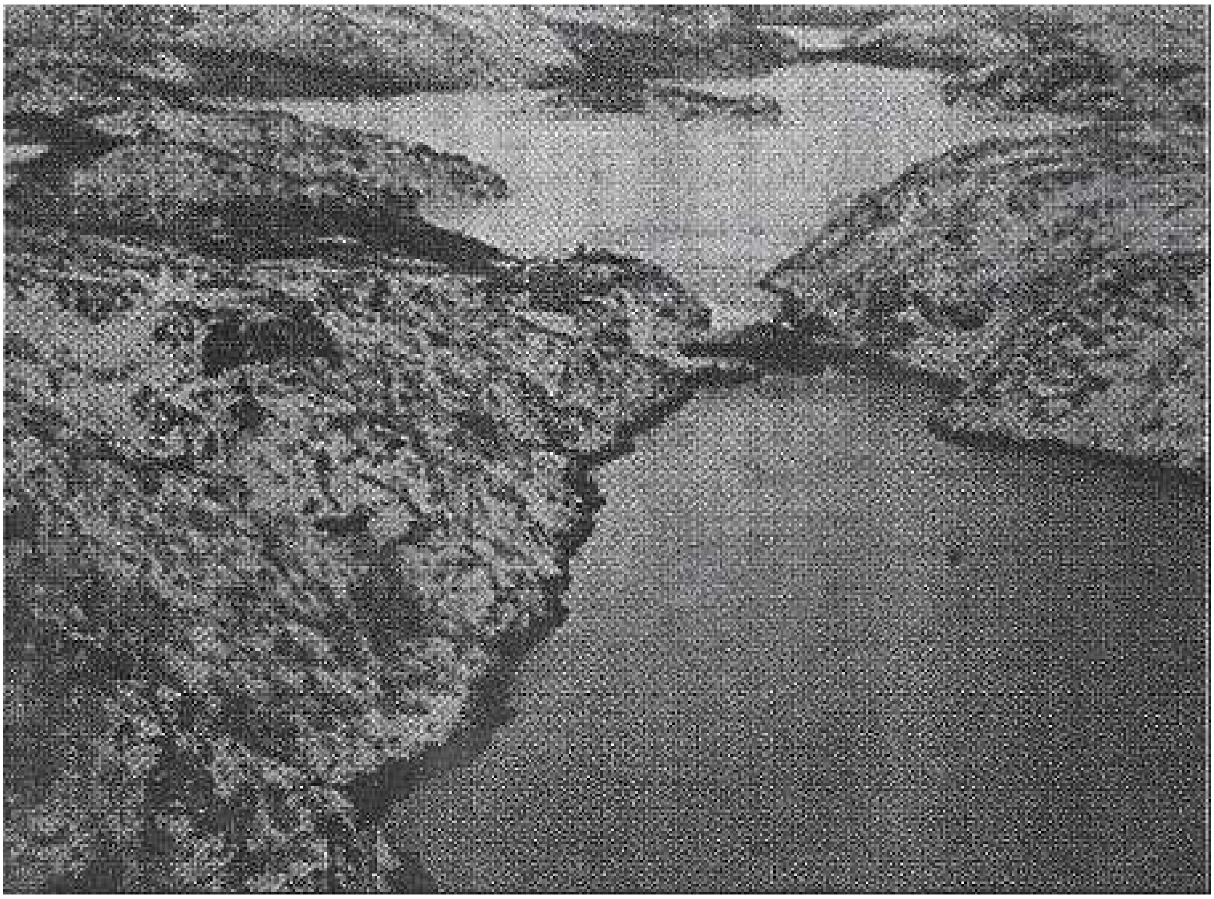
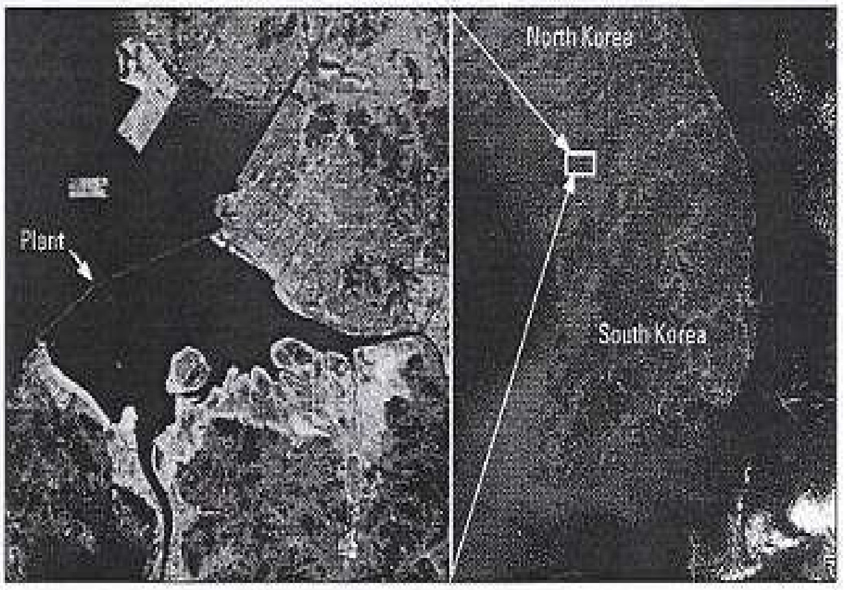
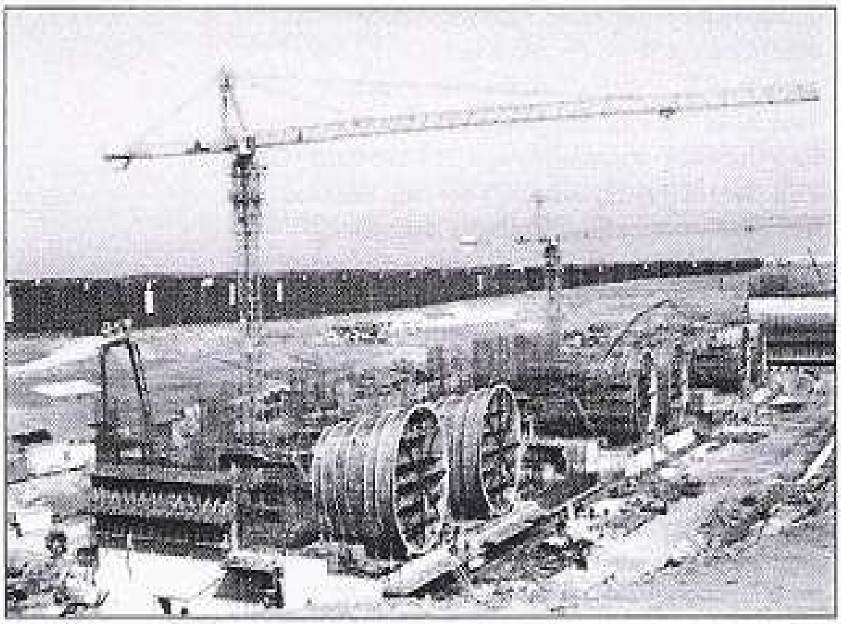


Figure 1. Kislogubskaya tidal plant in the Barents Sea. (Hydropower and Dams-Supplement, 2009)

Location of Lake Sihwa, South Korea (Source: Google Earth).





Installation of bulb turbine draft tube cones before concreting in 2008.

Figure 2. Lake Sihwa project region and turbines (Hydropower and Dams- Supplement, 2009)

Figure 3. Tucuruí in 2005. 8340 MW, 11% of Brazil's daily electricity supply. A frontal view of the 23 unit power house. (2005, Rolf Sternberg)

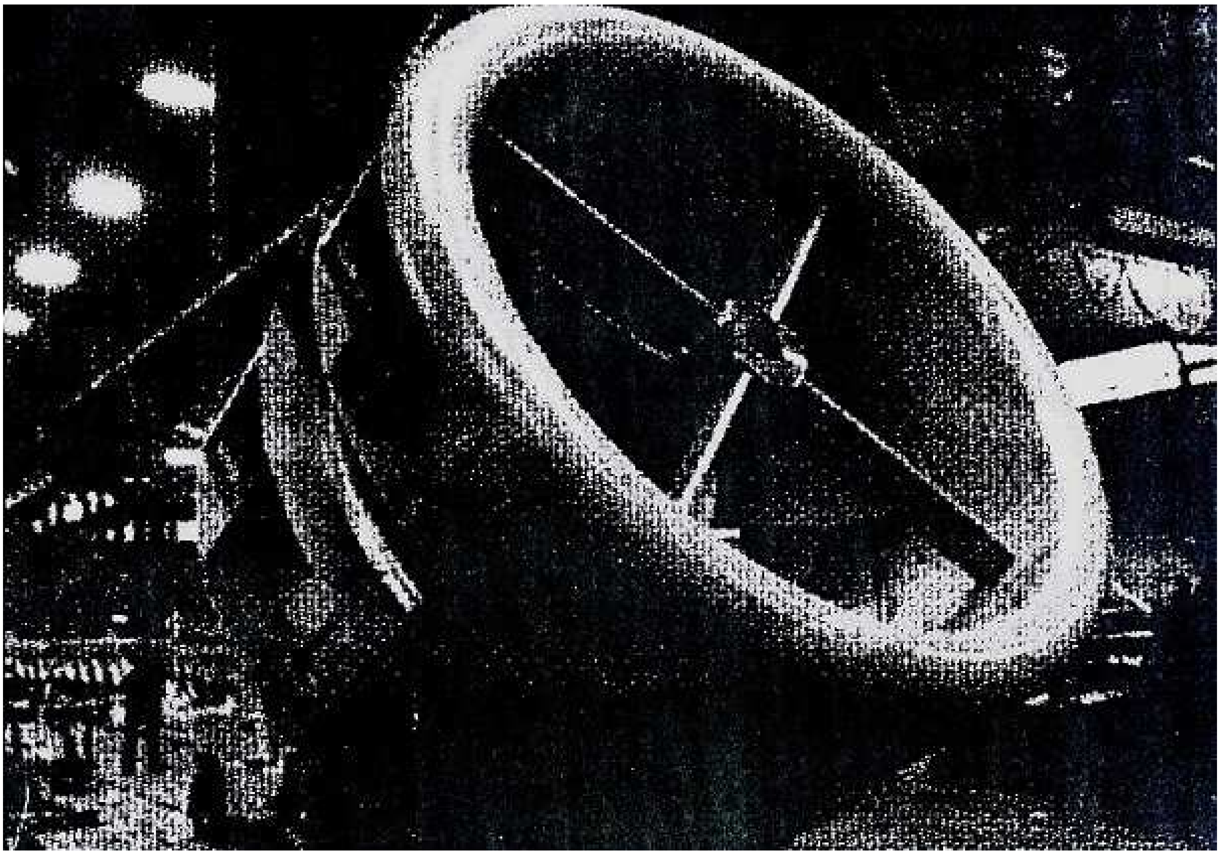


Figure 4. Hydrokinetic turbine- run-of-the-river unit. (Hydropower & Dams, 2009)

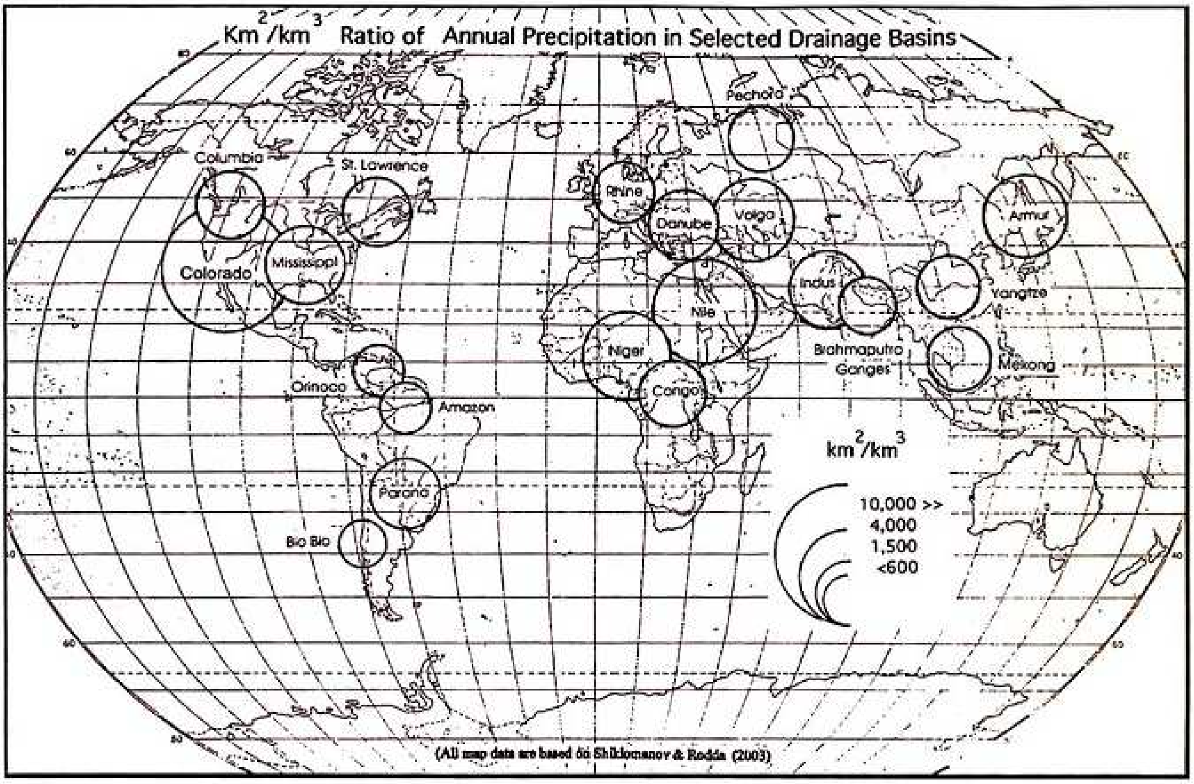


Figure 5. km^2/km^3 provides an approximation of water availability, this information can serve to assign reservoir size by the respective project engineer(s). (R. Sternberg, 2010)

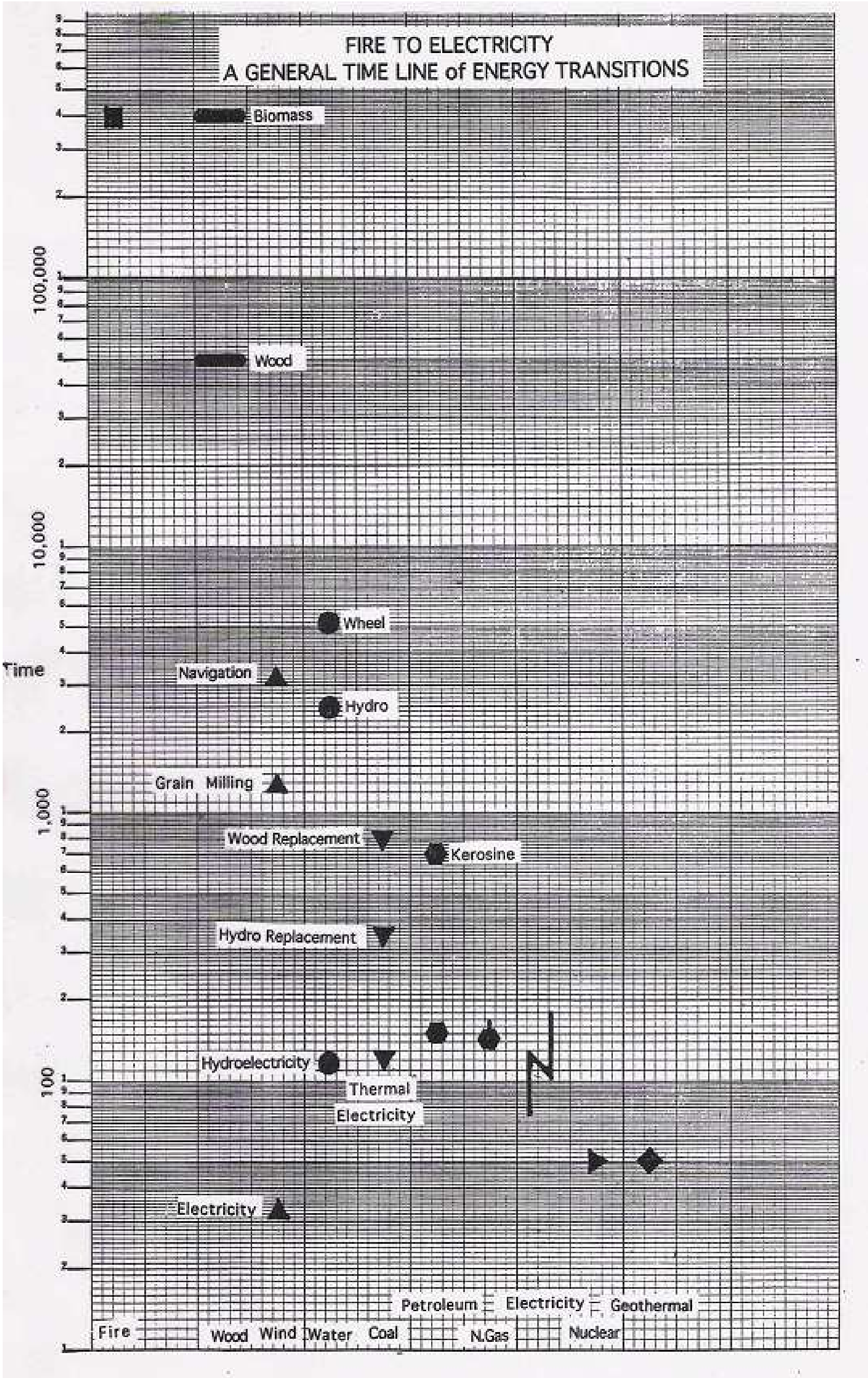

FIRE TO ELECTRICITY
A GENERAL TIME LINE of ENERGY TRANSITIONS
Biomass
Wood
Wheel
Navigation
Hydro
Grain Milling
Wood Replacement
Kerosine
Hydro Replacement
Hydroelectricity
Thermal
Electricity
Electricity
100,000
10,000
1,000
100
Time
Petroleum
Electricity
Geothermal
Fire
Wood
Wind
Water
Coal
N.Gas
Nuclear

Figure 6. Energy historic log graph registering time frame of sectorial growth. (R. Sternberg)

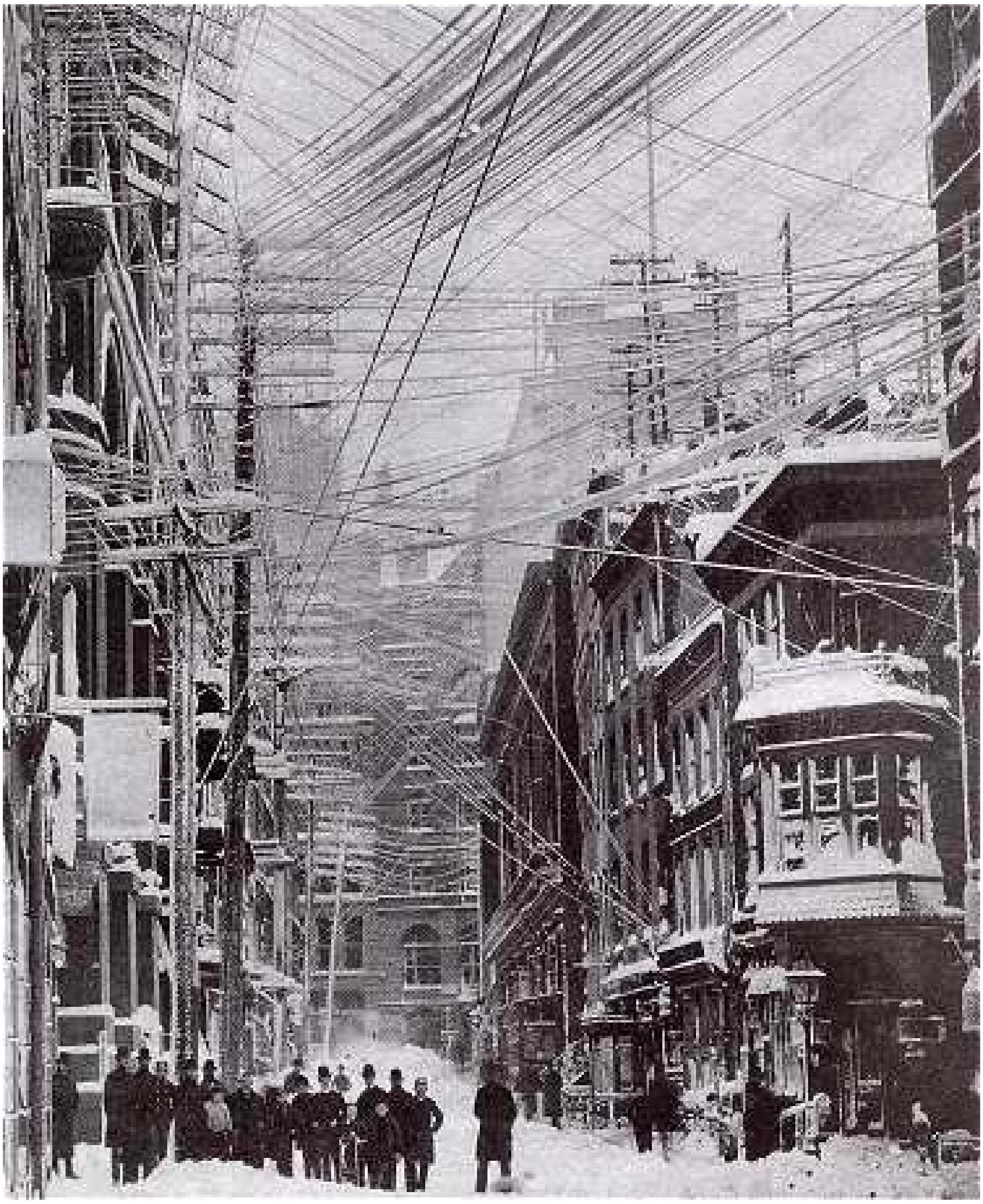


Figure 7. New York City, Lower Manhattan, 1888 Blizzard, power on the street, on line. (New York Times, N.D.)

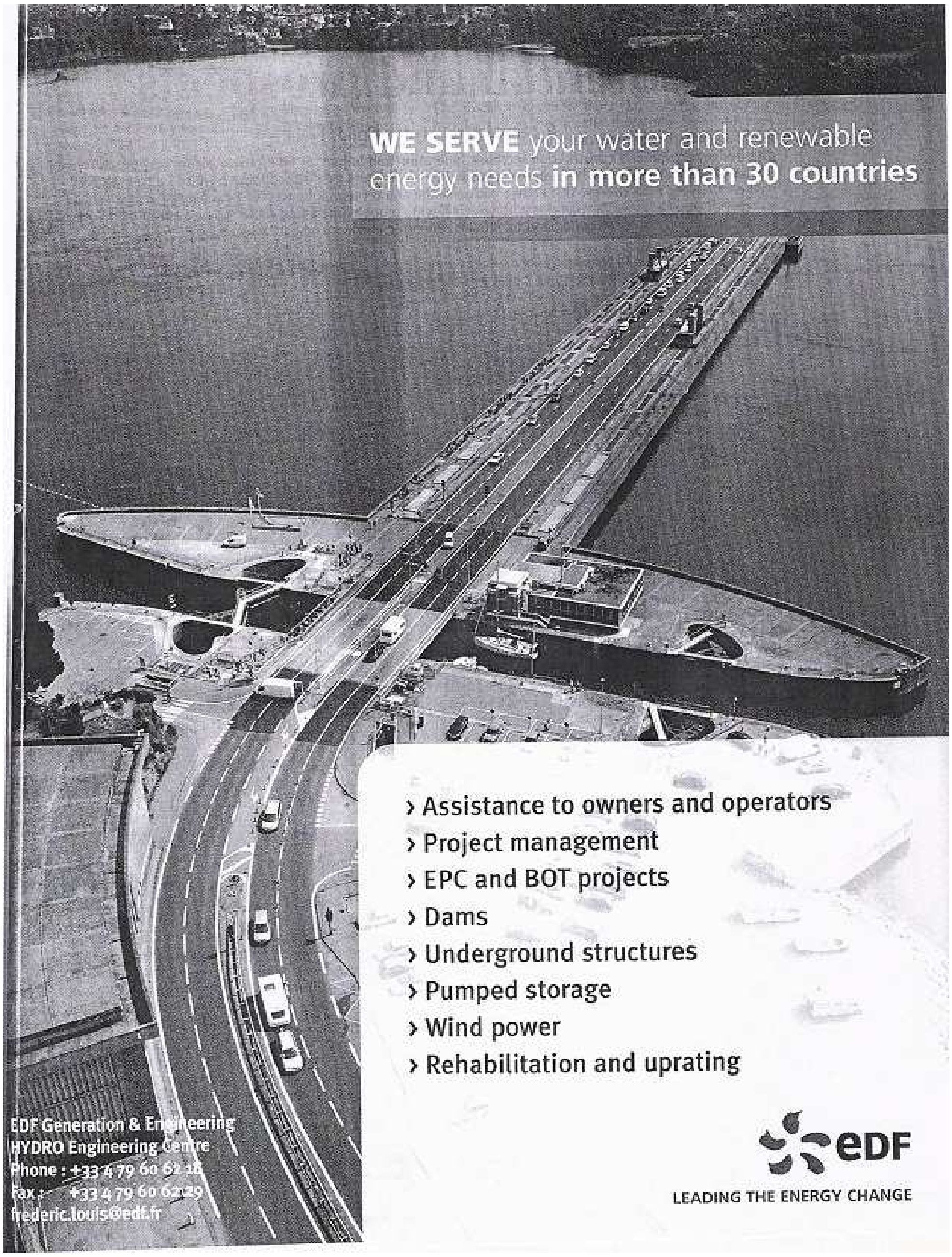


Figure 8. La Rance- a tidal wave project,, N.W. France, in operation since 1966. (Hydropower and Dams- Supplement, 2009)

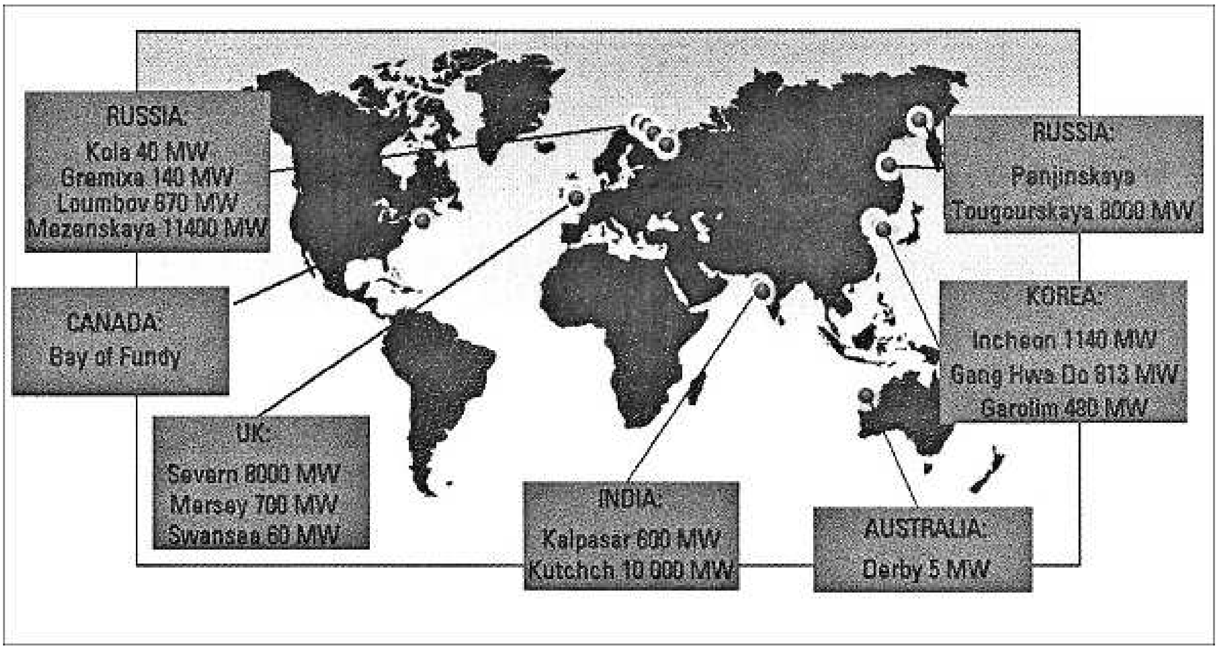


Figure 9. Tidal power stations planned as of March 2009. (Hydropower and Dams-Supplement, 2009)

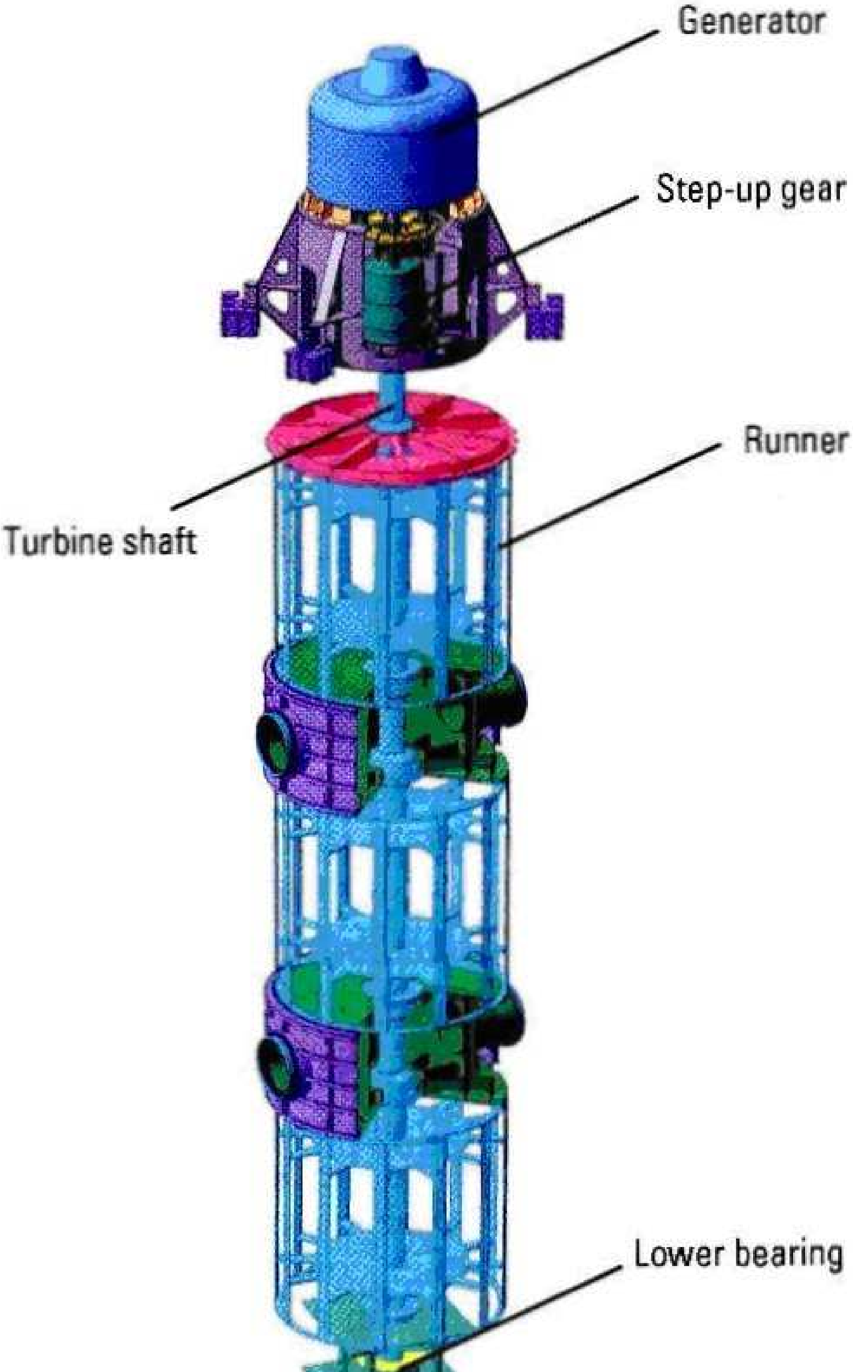

Generator
Step-up gear
Runner
Turbine shaft
Lower bearing

Figure 10. Tidal wave runner- Russian model can be installed in caissons or in civil infrastructure. (Hydropower and Dams- Supplement, 2009)

Table 1
Select river basin data for annual water availability.

Region	River basin	km^2	Water (km^3)	km^2/km^3	Mean Flow (m^3/s)
Asia	Yangtze	1810000	1003	1805	35000
	Ganges/Brahmaputra	1750000	1389	1260	20000
	Indus	960000	220	4364	3850
	Mekong	646000	459	1407	15900
	Armur	1860000	355	5240	12500
Europe	Danube	578300	176	3286	6450
	Volga	1360000	252	5397	8000
	Pechora	317000	137	2314	4060
	Rhine	103700	50.6	2050	2200
Africa	Niger	2090000	302	6920	5700
	Congo	3680000	1320	2788	42000
	Nile	2870000	161	17826	1584
North America	Mississippi	2980000	515	5786	17545
	Columbia	668000	237	2819	6650
	Colorado	637000	16	38813	168
	St. Lawrence	1026000	320	3206	10400
South America	Amazon	6920000	6920	1000	180000
	Parana	3100000	811	3822	19500
	Orinoco	1000000	1010	990	28000
	Bio Bio	21220	36	596	1230

Table 1.Select river basic data for annual water availability. (R. Sternberg)

Hydropower and Dams- Reports and Research: From 2002-2010

Year	Wave Action	Tidal Power	Run-of-the-River	Hydro-Kinetic	Pelamic	Other	#	%
2002	■■						2	2.2
2003	■■	■■					4	4.4
2004	■■■	■	▲		■		6	6.7
2005	■■■■	■					5	5.5
2006	▲ ■■	■				▲ ■	6	6.7
2007	■■■■	▲▲ ■■■■■■				▲ ■	14	15.5
2008	■■■■	▲▲▲ ■■■■■■ ■				▲ ▲▲ ■■	19	21.0
2009	▲▲▲ ■■■■■■	▲▲▲▲▲▲▲▲▲■■		■■■	■	■■	26	28.9
2010	■	▲ ■■	■■■	■	■		9	9.1
	32	37	3	4	3	11	90	99.8
Key:	■ Summary Report ▲ Research Report							

Table 2. Research studies and summary reports registering pace of reporting for nine years (2002-10). (Hydropower & Dams, volumes X-XVII, 2002-2010)

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