UNEXPLOITED RENEWABLE ENERGY TECHNOLOGIES FOR MARINE ENERGY SOURCES

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[References & Figures/Diagrams after page 4]
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SYNOPSIS
Britain, and many other countries have a coastline with inlets, and shallow water close inshore. There are also large areas of sea which could be harnessed to collect Wind Energy as Hydrogen, but which would have prohibitive equipment foundation costs for the currently used types of Wind Energy Collectors. These areas are prime sites for Renewable Energy Collection, from Wind and Tides, possibly incorporating Fish Farming in some of the concepts to be set forth. There are promising Technologies available for this Energy Collection which have so far remained largely unexploited. These are described together with their History, Applications to date, and possible Future Prospects, including Concepts for projects to apply them.

Author's Biography.
He is a Chemical Engineer with considerable experience in Energy Conservation and Renewable Energy. He is on the Energy Consultation panels for the DTI, Defra, and the National Assembly for Wales. The Grunhaus Project, for which the author is Secretary, and Professor Lewis Lesley of Liverpool, Convenor, is intended to bring together technical data on all forms of Sustainable Engineering and Renewable Energy on a Website. This paper is an extract of data being collected for that project. See www.grunweb.org.uk

KEY WORDS: HEAT PUMPING, HYDROGEN, HYDROPOWER, OFFSHORE ENERGY, PROCESS HEATING, TIDAL POWER, WIND ENERGY, WIND TURBINES.

INTRODUCTION

All Renewable Energy collection involves concentrating a dispersed Energy Source of little practical use, into a form which can be applied to the requirements of Mankind. In descending order of magnitude the UK percent Energy Useages are:

Heating and Hot Water [33], Transport Fuels [25], Process Fuels [23], Electric Power & Refrigeration [8], Chemicals [8], Cooking [3]. The figures given are indicative only. [Fig.1]

Two Marine Energy Sources are considered, Tidal rise and fall, which is totally predictable. And Offshore Wind power, which is more powerful, less predictable, and more variable . Both Energy Sources need at some point to be converted to Rotary Motion, but with the Technologies proposed, Tidal power can initially be collected as high pressure hydraulic power. Thus giving the ability to drive a wide variety of items of machinery, and allow some Energy Storage. Whereas Wind Energy is collected as Electricity, which cannot be stored in any quantity, and must be immediately "used". Albeit crude electricity can be easily converted to heat and stored.

The Marine Environment to be considered is all Coastal Tidal Water including Estuaries, the Offshore shallow waters of the North Sea, and similar locations, and deeper waters where energy can be transferred to shore in an economic form.

The author has been involved in wind turbine design and construction with Trimble Windmills, and has a long association with AUR Hydropower, the owners of a technology for harnessing Tidal Power. This paper aims to introduce a possibly valuable field for development of marine based Renewable Energy to a wider audience. In the expectation that initiatives will be forthcoming to finance and construct projects applying the technologies described below.

But as was said many years ago, upsetting the World's climate has cost a lot of money to do it, and will cost a lot more to undo it.[Ref.1] The investment required long term is comparable to all the investment in railways, coal mines and oil fields from 1840 to 1980. Having said that unlike an oil field which eventually runs dry, renewable energy lasts while the Sun lasts. And is tax free and inflation proof, while for any trading organisation it's investment cost can be written off against profits tax liabilities.[Ref.2]

cont page 2

ENERGY FROM THE TIDES

This form of energy has been harnessed from Roman times for small milling operations on coastal sites. No part of the UK is further than 70 miles from tidal water. The gravitational energy from the Sun and Moon move sea water up and down in a regular, predictable and constant pattern. Thus Britain is well placed to take advantage of this inexhaustible energy source. To do this either the flow of the tide must harnessed as it moves round these islands [Ref.3]. Or the sea must be channelled to flow from a high tide level to a low tide level, which is the approach of this paper. This involves creating "ponds" in the walls of which equipment is sited to generate energy from the flow. As the ponds will both fill and empty, the equipment must be capable of bi-directional flow.[Fig.2] The equipment must also be effective under conditions of flows below it's maximum capability, and have a high conversion of flow energy to mechanical or electrical energy.

WATER ENGINES

These conditions are met by a Water Engine.[Fig.3] The operation is that of two weighted floats being alternately raised and lowered by water entering the chamber underneath them, and then draining out of it. The flow is controlled by flap valves. Flow can be in either direction, as may be controlled by the valve programme.

The floats are linked to two sets of hydraulic rams, so that the force of the floats rising and falling is converted to hydraulic oil (or water) pressure. [Fig.4] This pressure stream can then be used to power machinery, including electricity generation equipment, heat pumps, and other rotating equipment.

The mechanism is essentially a pressure intensifier. In that the low pressure of a few feet of water is converted into 3-4000 psi hydraulic pressure. The operating range for single units is from 1ft to 10ft head of water, and is thus suitable for large flow, low head, installations in rivers, and for tidal power collection using "ponds". Higher heads can be handled by "cascade" installations of two or more units in series. Though reverse flow is thereby inhibited.

In the 1980's two machines were built and reported on by ETSU [Refs.4,5,6] [Fig.5] but since then
only two small test machines have been built. he mechanisms are simple and robust, and in volume production should be comparable in cost with other hydropower equipment. Maintenance should be simple, and given good construction parameters, the equipment should have a long life.
For example all parts in contact with sea water could be made of fibreglass or other non corroding materials.

A major cost however is the construction of the ponds. Three approaches can be considered for Tidal energy collection. The estuary approach as shown on [Fig.2], the Shoreline approach as shown in [Fig.6] and the open sea approach [Fig.7]. Both the last two envisage additional energy income being generated from Wind and Wave energy and from fish farming. The open sea approach is similar to that being pioneered by Tidal Electric off Cornwall, but using Water Engines, and adding the additional income generating items mentioned above. For estuary and inshore installations the hydraulic power could be piped ashore, have hydraulic accumulators included for some energy storage to help iron out demand peaks and troughs, and the driven items, heat pumps, generators or other machinery mounted well away from sea water.

HYDRAULIC POWER APPLICATIONS

The Estuary and Shorline approach benefits from the possibility that initially all power developed by Water Engines would be collected by an hydraulic main, and taken on shore. Where a central generating or other energy using facility could be set up, well away from the sea. Given suitable materials of construction the Water Engines could just act as pumps, delivering sea water under high pressure into the hydraulic main. In a similar manner to the London Hydraulic Power Company, which at its height in 1930 supplied 8000 machines with power through 186 miles of pipes.[Ref.7] Or Bristol's Avonmouth Docks, which were originally powered by hydraulics. [Ref.8] There are of course many inland applications for water engines, in locations with heads of 3m and below. But sadly while Eire has surveyed such sites, [Ref.9], the UK has only done surveys down to heads of 3m. Not below. [Ref.10]

HEAT PUMPING

A major potential application for Water Engines is to drive heat pumps. The Heat Pump centre in Sweden rates sea water as a very good heat source. [Ref.11] There is a major UK supplier of this type of equipment. [Ref. 12] The major energy advantage is that while electricity generation may give 60-65% of the Tidal Energy as usable power, a direct driven heat pump, which excludes electrical machinery, "adds" to the energy output to the extent that for every 100 units of hydro energy available, up to perhaps 250 units of heat energy can be delivered by a heat pump system. [Fig.8] The "extra" energy coming from cooling the sea.

WIND ENERGY COLLECTION

The basic mechanical principles of the currently popular three bladed large Wind Energy Collectors (they are not strictly turbines having only one rotor) go back to 1185 or before when Nicholas rented the "milling by the wind" (Molendium venti) from the Knights Templars in E. Yorkshire. And possibly as far back as when the "slave skilled in the manufacture of windmills" slew the Sultan Omar of Baghdad in 644 AD. A good history of wind energy developments from 1905 to 1972 can be found in [Ref.13].

A friend of Betz who is sometimes described as the "father of modern wind energy collection theory" [Ref.14], Hans Honneff, wrote a book on the use of contra-rotation, using two rotors one behind the other, driving the two halves of an electrical generator.Thus creating a true "Wind Turbine" [Ref.15] The concept was for very large wind turbines, three to a tower, 150m, dia, each, generating a total of 21 MW. The two rotors for each of the three turbines had a 120m, dia. set of magnets and coils as the electrical system, each rotor revolving separately from the other. Small (10m. dia.) models of the above were tested by the Third Reich Wind Energy Ministry, [1935-45].

In fan and turbine engineering the energy collected by two or more rotors in series is additive.[Ref.16] This point was confirmed for wind energy collection with model trials in 1976 by Simon Bromet (unpublished manuscript). Further confirmation of this fact was published recently following some trials by the California Energy Commission. But using a conventional alternator. [Ref 17] An attempt to the “additive” effect of contra-roation was made by Trimble Windmills in the period 1976-82. A small (5kW rated) machine was built, and a number sold to farmers and isolated sites for heating. [Ref.18] With some tap off for local electric power. The machines had a contra-rotating permanent magnet alternator, and sail wing blades attached to each half. Current collection was through slip rings. While the full additive effect shown by Mr Bromet was not achieved, probably due to the two sets of blades being too close together, a respectable Cpm of 0.37 was achieved. [Ref.19] Blade spacing requires further research and development. [Fig.9] <u>Note that contra-rotation electricity generation does not require a gearbox, thus saving costs and energy loss.</u>

Later the concept of "ganging up" many contra-rotating rotors was conceived due to the discovery of German work by the 3rd Reich Wind Energy Ministry (1934-45) indicating an interesting synchronous non electronic method. [Ref.20] Other work on this may be contained in a FIAT report, not yet traced. [Ref.21] This concept was called an Integrally Linked Multiple Array (ILMA) which was chosen for display at the Rolls Royce sponsored poster session at the 1988 Techmart Exhibition.. [Fig.10] [Ref.22] The system has yet to be tried out, albeit several wind energy collectors on one tower (single rotors) had been proposed earlier for Marine work [Ref.23] and tried out on land.[Ref.24] The latter unit had six rotors to give a total rating of 400 kW.

The rationale for many rotors, provided they can be cheaply mass produced and electrically linked is that as a Wind Energy Collector is an area for income, but a volume for cost, above a certain diameter is seems probable that the cost of many rotors will be less than one large rotor of the same rated output. This principle of "many circles" is found in piston engines. The original ILMA concept was put forward in 1983. [Ref 25] One potential advantage of this approach for marine work (and for wind turbines on buildings [Ref.26) is that rotors can be dispersed over the supporting structure, eg a redundant Oil Platform, without the need to have means to support the considerable overturning moment of a single large rotor. Losses due to breakdowns are minimised as not all the small rotors are likely to fail at one time. Due to rotors being point suspended (as per Honneff), loads on supporting stuctures can be considerable reduced, together with overturning moments, as this suspension converts side wind forces into a downward load on the supporting structures. This all potentially aids the erection of Wind Energy Collectors (WECs) on the dividing walls of tide ponds (see supra).
An important matter for future developments is to change the alternator design for ILMA from an axial air gap, as is found in most electrical generators, to a radial air gap. The latter are found in small WEC's and a motor in this configuration has been reported. [Ref.27] The original Trimble alternator, designed and manufactured by Clarke Chapman at Gateshead was robust, virtually trouble free (one ran for over 10 years with no maintenance attention), efficient, but very heavy and costly.

Honnef placed his “generating ring” almost at the tip of the rotors, where the angular speed is greatest. A similar approach is required with ILMA units, especially as the center one third of any WEC is useless for energy collection, and the wind in this area can with advantage be directed outwards with a nose come. A theoretical study of contra-rotating electrical machines is known of. [Ref.28] Recently reported work indicates a considerable reduction in the cost and weight of permanent magnet alternators [Ref 29]. he single rotor concept however has had it's advocates for Marine use. Honnef envisaged very large rotors, barge mounted, with the energy collection at the base of the rotors rather than all round the edge. A similar proposal for a large single rotor made by Mullett in 1956, is quoted by Bockris. [Ref.23]

APPLICATIONS FOR MARINE RENEWABLE ENERGY

The first application is clearly to bring it onshore.

Hydraulic Power from Water Engines, as noted above to drive Heat Pumps, abstracting heat from the sea, to heat premises close to the shoreline. In the Humber estuary for instance these could provide heating for the extensive greenhouse installations in the area. Power mechanical equipment directly without the interspersion of electricity (more energy efficient). And generate electricity.

Electricity from WEC's. The usual application with synchronous generation (feasible with the ILMA concept, if the Kloss electric linkage theory proves effective) is direct use, fed into the Grid in UK.

If generated as "crude" (asynchronous) current by allowing the WECs to "run with the wind", which improves energy collection efficiency, the current can be stored as high temperature heat from resistance heaters in Cowper Stoves, to provide Process Heat, which, as noted above, is a much greater energy demand in UK than electricity per se. [Ref.25]

This could be applied in the Chemical Industries, and in Ireland, Scotland and Wales for whiskey distilling. [Ref.30] It might also be used for powering a superheater section in a Nuclear Power Station's steam circuits, whose temperature conditions often leave something to be desired.

DC electric current can be used to fix atmospheric Nitrogen (Birkeland & Eyde process, pioneered by Norsk Hydro). Which has been examined on a small scale in Canada, using a "nitrolyser". [Ref.31]

An application for both on and off shore is Hydrogen production from sea water by Electrolosis. [Refs.23,32] This gas is becoming increasingly considered as a Road Transport Fuel. (Second largest UK energy usage). It can also be used to convert Coal to Liquid fuels. [Refs.23, 33, 34 & 35] And has been considered for processing domestic waste to fuel. [Ref.36] This technology might provide an extended life for redundant oil platforms. Although existing oil pipelines might be metallugically unsuitable for its delivery to shore. And it cannot be mixed with Natural Gas to add to the latter's energy content as all gas using appliances would have to be altered. [Ref.37]

Offshore, [Ref.23] offers an interesting concept of the electrolosis taking place at depth in sea water. Providing Hydrogen under compression for transport and storage, and a means of disposing of the chlorine produced though dispersion in the sea.

However extensive enquiries over the past few months in both the USA and the UK have found no references to this technology having been tried out. Albeit Hydrogen compression at the point of production by electrolosis is being investigated in the USA. [Ref 38] The chlorine might however have commercial uses too.

Not everyone is convinced of the economic viability of a “Hydrogen Economy”. Ref 39] But the possible economic advantages of the technologies discussed above could change this view ? Certainly one island off Norway, Utsira, has recently gone to a Wind and Hydrogen energy supply system. Some of the wind energy is used to produce Hydrogen, which through Fuel cells produces electricity and heat when no wind power is available. [Ref 40]

CONCLUSIONS

Development of the two technologies described above, and the applications for the use of the energy generated could provide UK industry with worthwhile programmes to capture the very considerable renewable energy sources around the UK, and other islands. The cost will be heavy, but effectively set on, this development could go a considerable way to making the UK less dependant on oil in the future, and by reducing Carbon Dioxide emissions, help tackle the problem of Global Warming.

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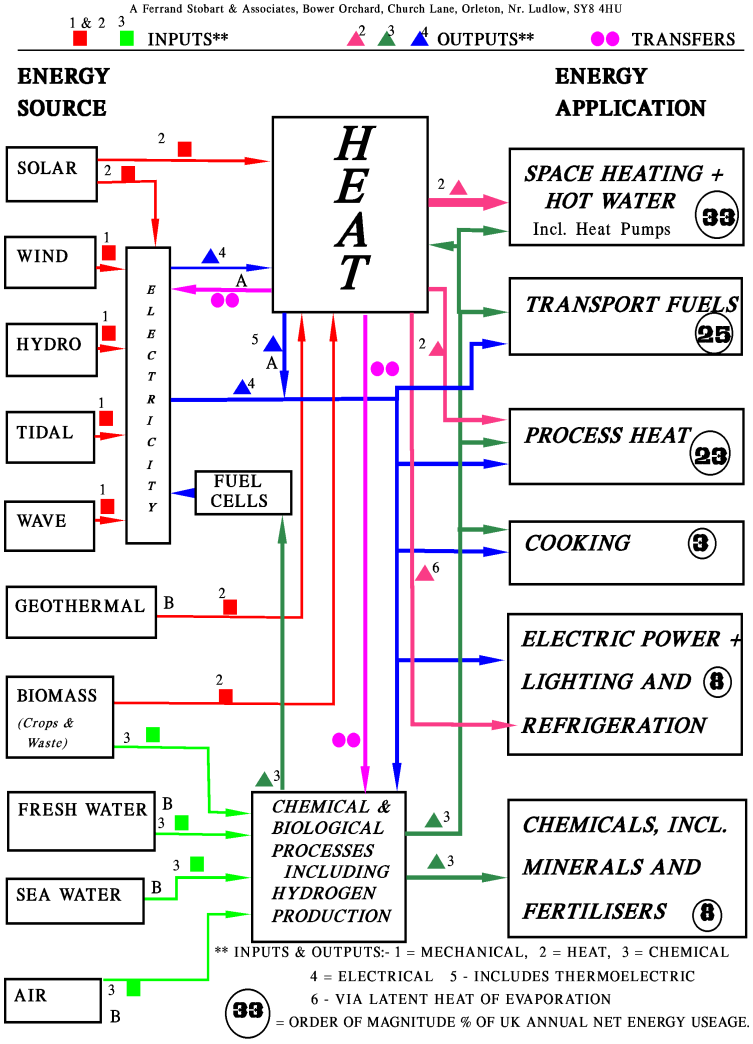
Fig 1

RENEWABLE ENERGY PROCESS DIAGRAM

Drawn by A.F.STOBART, BSc (Chem Eng), Nov 1994, Revised May 2003 & August 2004

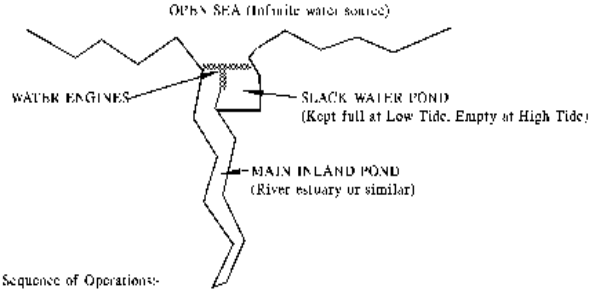
A Ferrand Stobart & Associates, Bower Orchard, Church Lane, Orleton, Nr. Ludlow, SY8 4HU



NOTES: AA: Via Steam Generation & Thermoelectrics, BB: Heat Sources for Heat Pumps

CONCEPT FOR WATER ENGINES IN A TIDAL POWER ROLE.

A Ferrand Stobart & Associates, Sept 1996



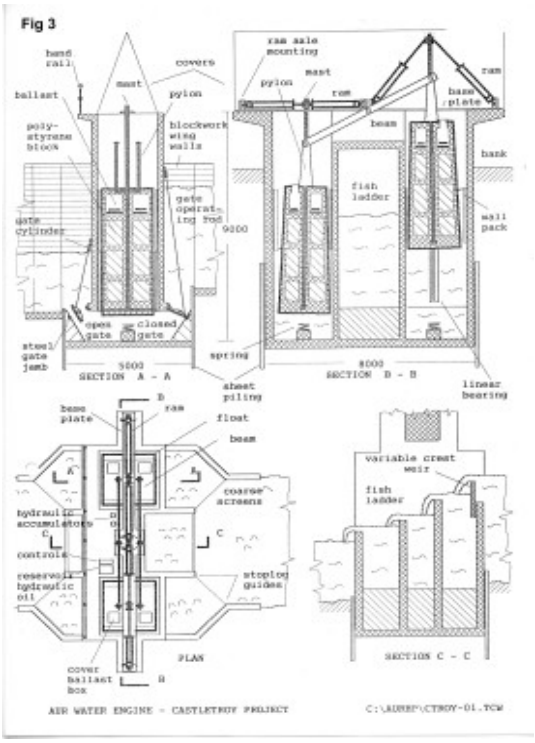
Sequence of Operations:-

1/. High Tide, start of slack water, Main Pond filling.
Slack Water Pond empty, starts filling
2/. High Tide, slack water. Slack Water Pond filling
3/. High Tide, start of ebb. Main Pond starts emptying
Slack Water Pond full, shut off.
4/. Low Tide, start of slack water, Main Pond emptying,
Slack Water Pond starts emptying.
5/. Low Tide, slack water. Slack Water Pond emptying.
6/. Low Tide, start of flood. Main Pond starts filling.
Slack Water Pond empty, shut off.

NOTE:- Consideration can be given to mounting Water Engines on pontoons, to give constant "head" while in operation, except at very high and very low water.

Fig 2

Fig 3



A Fox and Sloan & Associates February 1996

Fig 4

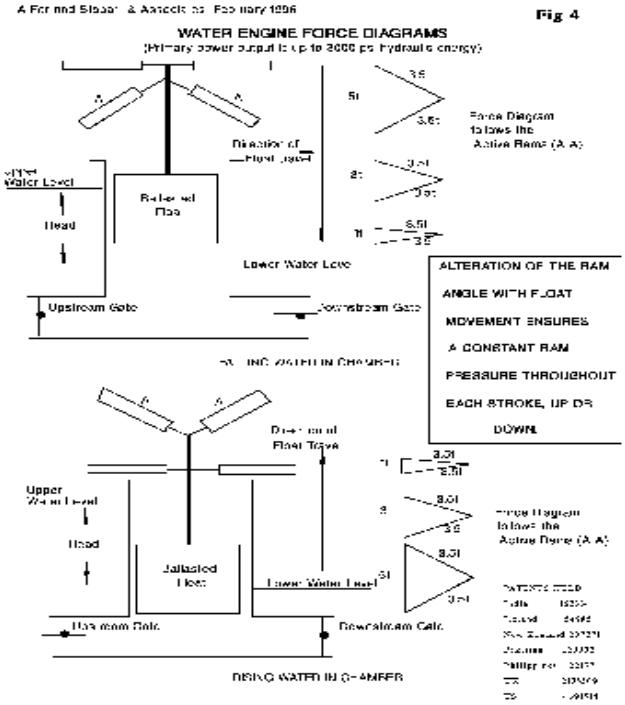


Fig 5

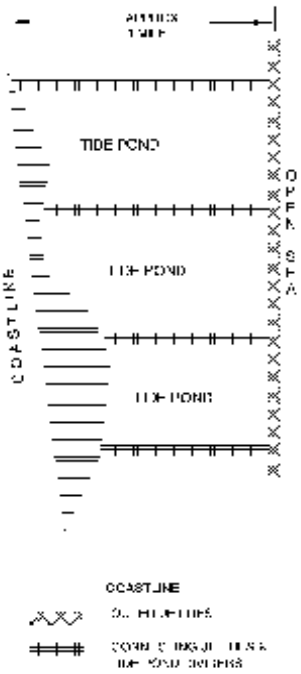
NEWARK MILL

The single float Water Engine is housed in the small brick building at the centre of the picture.

GIBBONS MILL

INTEGRATED OFFSHORE RENEWABLE ENERGY CONCEPT

Fig 6



Two major costs of Offshore Wind Turbines are their foundations and the connection to the Electricity Grid.

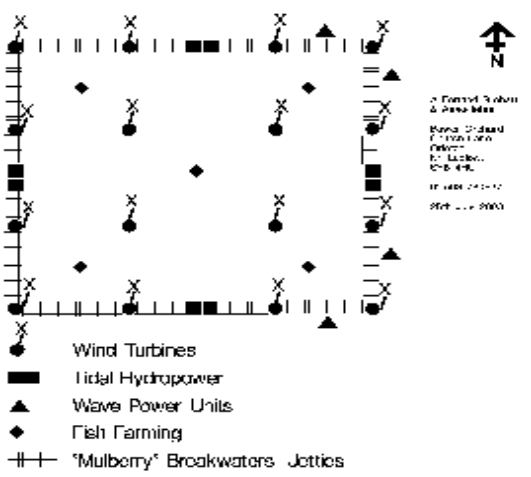
It is suggested that if offshore wind energy projects were combined with:
Tidal Power
Wave Power
Fish Farming
Then the spreading of the construction costs across these additional sources of energy streams would produce some major financial benefits.

In addition, on the English North East and the Welsh South coasts, there could be a considerable market for Hydrogen. Both for chemical processes and Coal Hydrogenation for liquid transport fuels. Thus providing a "storeable" product from Wind Energy. In certain areas it might also be possible to consider Process Heat or delivering "low" wind generated electricity to electrically heated **Cowper Stoves**.

In the shallow waters off the English East Coast *Mulberry* type construction could be considered. Both for the main offshore jetties and the connecting ones. The latter also providing supports for energy transfer or shore bus access for maintenance. See sketch opposite.
All jetties would have tidal power units built into them with controlled filling and emptying of the ponds in line with local conditions (See house on Low Head Hydropower). Wind Turbines would be mounted on top of the jetties. And possibly wave power units fixed on the seaward side of the main jetties.
The ponds could be used for fish farming. An additional benefit could be the prevention of **Coastal Erosion** which is harmful to the East Coast in particular.

NOTE: Tide Ponds to be sized so that the Tidal Power Units will empty or fill them within half a tide cycle.

Fig 7



THE WAFTEC
The Wind, Wave, Fish and Tidal Energy Centre

Fig 8

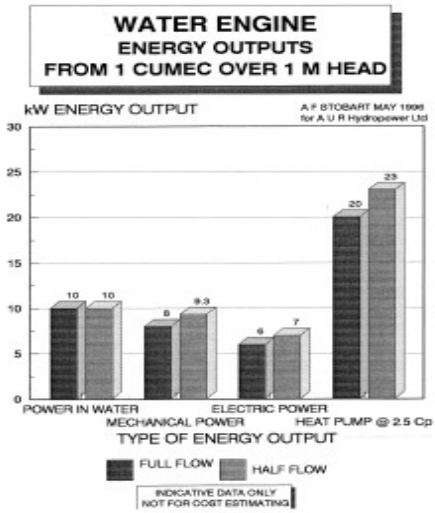


Fig 9

THE TRIMBLEMILL
A 5 kW contra-rotating sail wing wind turbine for heating applications
UK Manufacture, 1978 - 82

Fig. 9

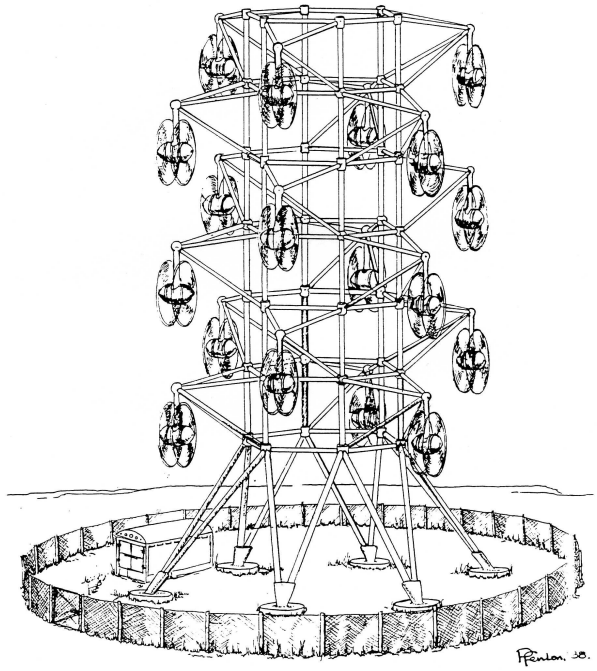
6m dia true Wind Turbine, with ductile iron support tower. Balanced tail for out of wind turning in high winds, sailwing blades on aluminium spars. Main application heating, hot water or hot air with tap off for limited electric power for battery charging.

Artists Impression of a

270 kW INTEGRALLY LINKED MULTIPLE ARRAY (rated @ 13m/sec wind)

"ILMA" (c) Copyright A.F. Stobart 1982

(Ilma is the Finnish for Wind)



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RESOURCE CONSERVATION

Fig 10