TIDAL ENERGY

B. Sørensen
Roskilde University, Denmark

Keywords : Resources, Environmental Considerations, Technology

Contents

Summary

Tidal energy resources and the technologies for extraction of power from them are reviewed. Economic and environmental impacts are discussed.

1. Resources

Tidal forces are due to the gravitational attraction between the Earth (with the water surrounding most of it) and other bodies in the Solar System, notably the Sun itself and the Moon. They would contribute a maximum tide amplitude of 0.16 m and 0.36 m respectively, if the Earth was totally covered by oceans and if the tidal motion were not coupled to the Earth's rotation. In this case, the period would be a solar or lunar day. In practice, the interference with shoreline profiles leads to a considerably more complex tidal pattern, with maximum amplitudes at certain locations of up to 12 m. The phase difference between solar and lunar tides gives rise to the neap and spring tide phenomenon, but maximum coherence of the two main tidal forces will occur only every 1600 years (which happened last in 1433, cf. Sørensen 1979).

The energy dissipated from tidal waves due to friction against continents has been estimated by King Hubbert (1971), and if it is assumed to correspond to the total energy input by the celestial forces, these can be estimated to some 3 TW (see Figure 1), i.e. similar to that of wave power, globally.

Maximum tidal range and estimated power associated with a given area (e.g. an inlet) are given for selected locations in Figure 2. The power is calculated as

$$P = gd\, AH^2/T$$

Where g is the gravitational acceleration at the Earth's surface, d the density of water, A the area considered, H the height difference between high and low tide, and T the tidal period (Sørensen 1979). Tidal power stations have been considered or built at all the

locations indicated in Figure 2.

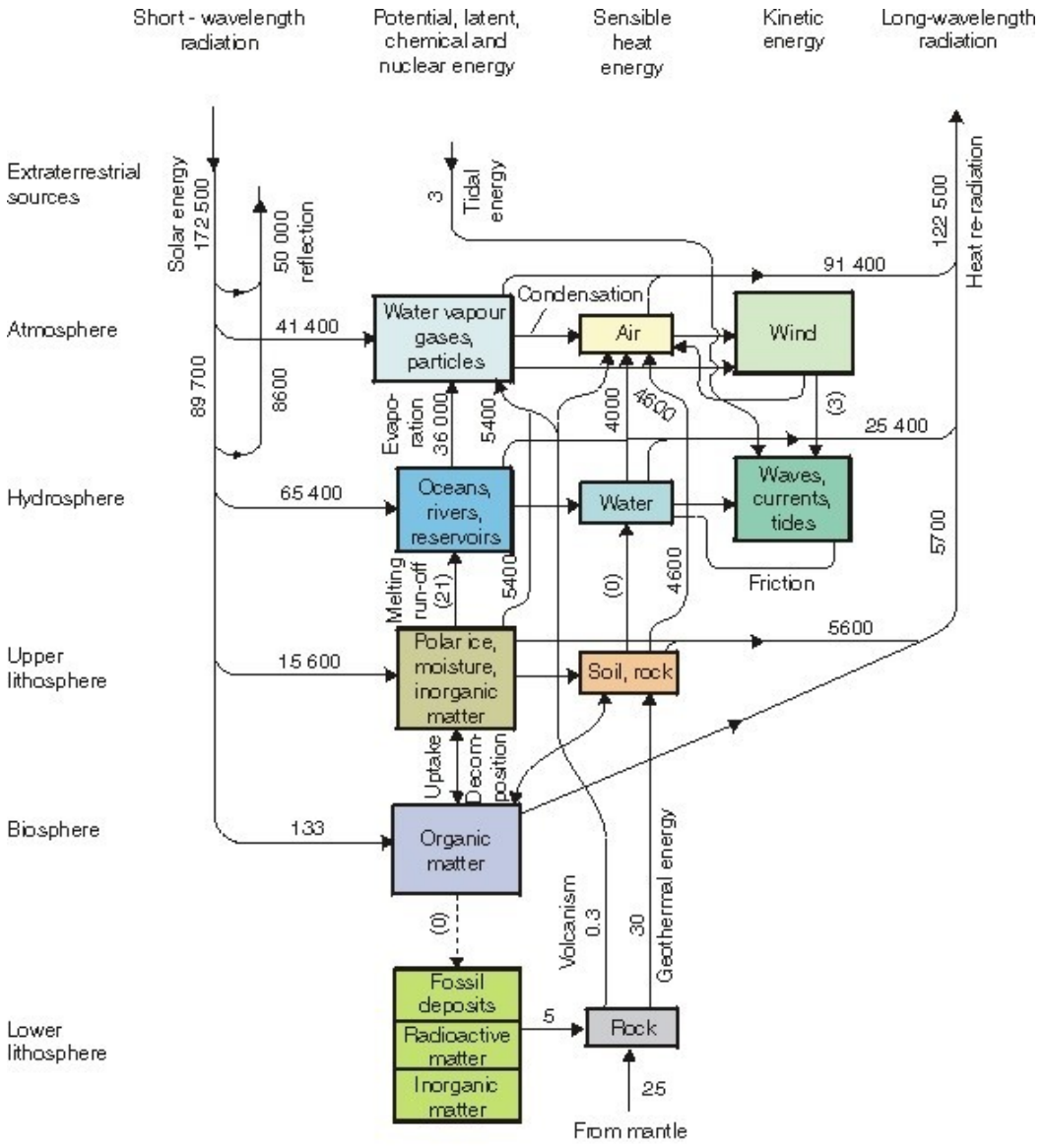

Figure 1. The natural energy cycle of the Earth (TW) (Sørensen 1979).

Figure 3 gives a more detailed map of the tidal ranges H in Northern Europe, exhibiting in Severn Strait and the La Rance Bay some of the highest tidal ranges in the world. The condition for exceptionally high tides to occur in a given inlet is the creation of a resonant condition. This has been investigated by Wehausen and Laitone (1960) and they find that the simplest condition for resonance is $L = 35\ 000\ \sqrt{D}$, where L is the length of the inlet and D its depth. Estuaries, such as the Severn, fulfill this condition very well.

The total exploitable tidal resource in Western Europe is estimated at 54 GW or roughly

100 TWh per y, 90 per cent of which is evenly split between the UK and France (Cavanagh et al. 1993).

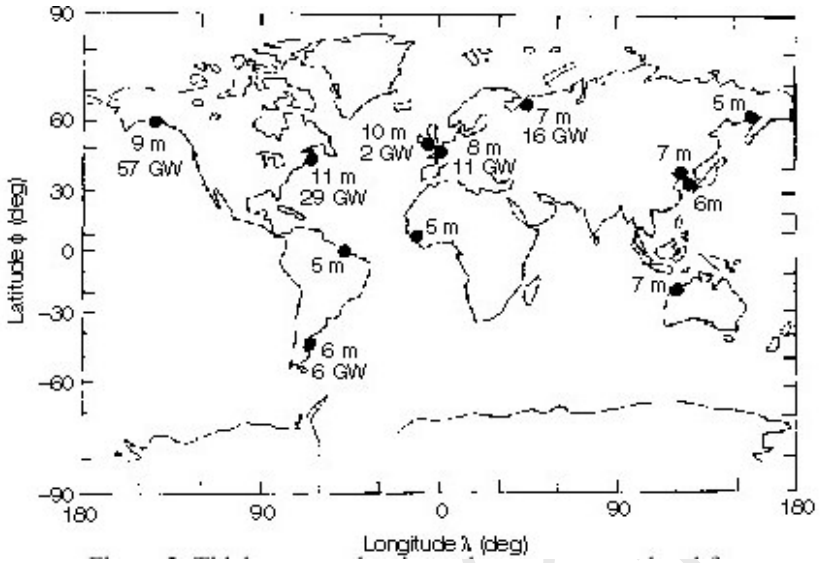

Figure 2. Tidal range and estimated average power level for a number of proposed barrage sites (Sørensen 1979).

-
-
-

Bibliography and Suggestions for further study

A. Wokaun. Beyond Kyoto: The risks and how to cope. UN Framework Convention on Climate Change. Bonn, Germany, 16-25 June 2004

Al-Karaghouli A.A., Alnaser W.E. (2004), *Experimental comparative study of the performance of single and double basin solar-stills*. Appl Energy **77**(**3**), pp. 317-25.

Al-Karaghouli A.A., Alnaser W.E. (2004), *Performances of single and double basin solar-stills.* Solar Energy **78**(**3**), pp. 347-54.

Al-Shammiri M., Safar M(1999). Multi-effect distillation plants: state of the art. Desalination , 126:45-59.

Andre H (1976) Transaction of the IEEE. PAS-95(4), 1038-1044.

Baker A (1987) Tidal Power. *UK IEE Proc.* 134, 392-398.

Bay of Fundy Tidal Power Review Board (1977) *Reassessment of Fundy Tidal Power*. New Brunswick.

Bernshtein L (1972) Kislaya Guba experimental tidal power plant and problems of the use of energy. *Tidal Power*. New York: Plenum Press.

Cavanagh J, Clarke F and Price (1993) Ocean Energy Systems. *Renewable energy sources for fuels and electricity* (eds T Johanssons, H Kelly, A Reddy and R Williams) pp. 513-547. Washington DC: Island Press.

Chafik, E., 2003. A new type of seawater desalination plants using solar energy. Desalination

Clarke F (1981) Prospects for tidal power. *Long-term energy sources* (eds R Meyer and J Olsen) pp. 1305-1333. Boston: Pitman.

Corrado Sommariva ,(2010),COURSES IN DESALINATION, Thermal Desalination

Cotillon J (1979) La Rance tidal power station, review and comments. *Tidal Power and Estuary Management:* Colston Papers # 30. Bristol: Scienctechnica.

Delyannis E. (2003), *Historic background of desalination and renewable energies.* Solar Energy **75**(**5**), Elsevier pp. 357-66.

EC (1995) *The potential for tidal power within the European Community*. To be published (figures quoted by Cavangh, Clarke and Price R, 1993).

ETSU (1991) *Mersey Barrage feasibility study, stage* 2. Harwell: Report TID 4071.

Florides G., Kalogirou S. (2004), *Ground heat exchangers – a review.* Proceedings of third international conference on heat power cycles, Larnaca, Cyprus, on CD-ROM.

Fundy Tidal Power Workshop (1990) Unpublished contributed papers.

García-Rodríguez L. (2003), "Renewable energy applications in desalination: state of the art", Solar Energy 75, 381-393.

García-Rodríguez, L., 2002, Seawater desalination driven by renewable energies: a review. Desalination 143: 103-113

Gregorzewski, A. and Genthner, K., High efficiency seawater distillation with heat recovery by absorption heat pumps. Proceedings of the IDA World Congress on Desalination and Water Reuse, pp. 97-113, Abu Dhabi, November 18-24, 1995.

Kalogirou S. (2003), *The potential of solar industrial process heat applications.* Appl Energy, **76**(**4**), pp. 337-61.Lysen E. (2003), *An outlook for the 21st century.* Renew Energy World, **6**(**1**), pp. 43-53.

Kalogirou S. (2004), *Solar energy collectors and applications.* Prog Energy Combust Sci, **30**(**3**), pp. 231-95

Karameldin, A. Lotfy and S. Mekhemar (2003), *The Red Sea area wind-driven mechanical vapor compression desalination system*, Desalination **153**, Elsevier pp. 47-53.

Kiilerich A (1965) Oceangrafi. Copenhagen: Gjellerup.

King Hubbert, M (1971), *Scientific American*, September, pp 60-87.

Kudish A.I., Evseev E.G., Walter G., Priebe T. (2003),*Simulation study on a solar desalination system utilizing an evaporator/condenser chamber*. Energy Convers Manage **44**(**10**), Elsevier, pp. 1653-70.

La Rance 20th anniversary colloquium (1986) Unpublished contributed papers.

M.A. Darwish , Iain McGregor, (2005), *Five days' Intensive Course on - Thermal Desalination Processes Fundamentals and Practice*, MEDRC & Water Research Center Sultan Qaboos University, Oman

Millow B. and Zarza E., Advanced MED solar desalination plants. Configurations, costs, future – Seven years of experience at the Plataforma Solar de Almería (Spain), Desalination 108, pp. 51-58, 1996.

Müller-Holst, H., 2007. Solar Thermal Desalination using the Multiple Effec Humidification (MEH) method, Book Chapter, Solar Desalination for the 21st Century, 215–225.

Parekh S., Farid M.M., Selman R.R., Al-Hallaj S. (2003), *Solar desalination with humidification-dehumidification technique – a comprehensive technical review.* Desalination **160**, Elsevier pp. 167-86.

Sayig A.A.M. (2004), *The reality of renewable energy*. Renewable Energy, pp. 10-15.

Sørensen B (1999) *Renewable Energy*. London: Academic Press.

Soteris A. Kalogirou (2005), *Seawater desalination using renewable energy sources*, Progress in Energy and Combustion Science **31**, Elsevier, pp. 242-281.

Thomson M., Infield D. (2003), *A photovoltaic-powered seawater reverse-osmosis system without batteries*. Desalination **153**(1-3), pp. 1-8

Tiwari G.N., Singh H.N., Tripathi R. (2003), *Present status of solar distillation.* Solar Energy 75(5), Elsevier, pp. 367-73.

Tzen E., Morris R. (2003), *Renewable energy sources for desalination.* Solar Energy **75**(**5**), Elsevier, pp. 375-9.

UK DoE (1989) *The Severn Barrage Project: General Report*. Energy Paper # 57. HMSO.

United Nations, Water for People, Water for Life – UN World Water Development Report, UNESCO Publishing, Paris, 2003.

Wehausen J and Laitone E (1960) *Handbuch der Physik*, 9(III), (ed S Flügge), pp. 446-778. Berlin: Springer.

Wiseman, R., Desalination business "stabilised on a high level" – IDA report, Desalination & Water Reuse 14(2), pp. 14-17, 2004.

World Energy Conference (1992) Ocean energy. Ch. 3 in *Committee on renewable energy sources: opportunities and constraints 1990-2020*. London.