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Research Article

Build resources against future uncertainty - A review on alternative resources in Oman

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ABSTRACT

Energy demand is expected to grow in the twenty-first century as more countries seek a better quality of life for their citizens. The energy demand will be met by a global energy mix that is undergoing a transition from an energy portfolio dominated by fossil fuels to an energy portfolio that includes a range of fuel types. Fossil fuels such as coal, oil, and gas were the fuel of choice during the last half of the twentieth century. Forecasts of the twenty-first century energy mix show a gradual transition from the current dominance of fossil fuels to a more balanced distribution of energy sources. Oman's major source of revenue i.e. oil reserves are declining as years gone by and efforts are being implemented to diversify the Oman's economy away from the oil sector. Technical advancement will play a major role to the mobilization of new reserves and the increase in the life time of present reserves. This paper presents a review of Oman's fossil fuel reserves and the scope of alternative resources for Oman's sustainable development of energy.

Key words: Fossil fuel, oil, natural gas, coal, wind energy, solar energy,

INTRODUCTION

Oman's Minister of Oil and Gas announced in April 2006 that the country planned to invest $10 billion in upstream oil and natural gas projects during the next five years. Much of this effort will focus on enhanced oil recovery (EOR), initiatives to improve recovery rates at several of the country's oil fields. Oman also plans to increase exploration and production (E&P) activities, although the natural gas sector will receive much of this investment[1]. As there is evident of depletion in Oman's oil & gas reserves, attention should be given seriously to the alternatives. The first alternative, of course, is renewable, which include solar energy in its various forms, biomass energy, wind power, geothermal etc.

Decades of technological progress have seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants and solar thermal collectors move steadily into the mainstream. The global market for renewable energy is growing dramatically; in 2006 its turnover was US$ 38 billion, 26% more than the previous year. The time window for making the shift from fossil fuels to renewable energy is still relatively short. Within the next decade many of the existing power plants in the OECD countries will come to the end of their technical lifetime and will need to be replaced. But a decision taken to construct a coal power plant today will result in the production of CO_2 emissions lasting until 2050. So whatever plans are made by power utilities over the next few years will define the energy supply of the next generation. We strongly believe that this should be the "solar generation". While the industrialized world urgently needs to rethink its energy strategy, the developing world should learn from past mistakes and build its economies from the beginning on the strong foundation of a sustainable energy supply. A new infrastructure will need to be set up to enable this to happen. Renewable energy could provide as much as 35% of the world's energy needs by 2030, given the political will to promote its large scale deployment in all sectors on a global level, coupled with far reaching energy efficiency measures. By choosing renewable energy and energy efficiency, developing countries can virtually stabilize their CO2 emissions, whilst at the same time increasing energy consumption through economic growth. OECD countries will have to reduce their emissions by up to 80%. There is no need to "freeze in the dark" for this to happen. Strict technical standards will ensure that only the most efficient fridges, heating systems, computers and vehicles will be on sale. Consumers have a right to buy products that don't increase their energy bills and won't destroy the climate.

OMAN'S OIL RESERVES

Oil will not just "run out" because all oil production follows a bell curve. This is true whether we're talking about an individual field, a country, or on the planet as a whole. Oil is increasingly plentiful on the upslope of the bell curve, increasingly scarce and expensive on the down slope. The peak of the curve coincides with the point at which the endowment of oil has been 50 percent depleted. Once the peak is passed, oil production begins to go down while cost begins to go up. In practical and considerably oversimplified terms, this means that if 2005 was the year of global Peak Oil, worldwide oil production in the year 2030 will be the same as it was in 1980. However, the world's population in 2030 will be both much larger (approximately twice) and much more industrialized (oil-dependent) than it was in 1980. Consequently, worldwide demand for oil will outpace worldwide production of oil by a significant margin. As a result, the price will skyrocket, oil dependant economies will crumble, and resource wars will explode[2] . **Figure 1** indicate the oil reserves of Middle East countries[1], which shows Oman is at seventh position with an oil reserve of only 5.5 billion barrels.

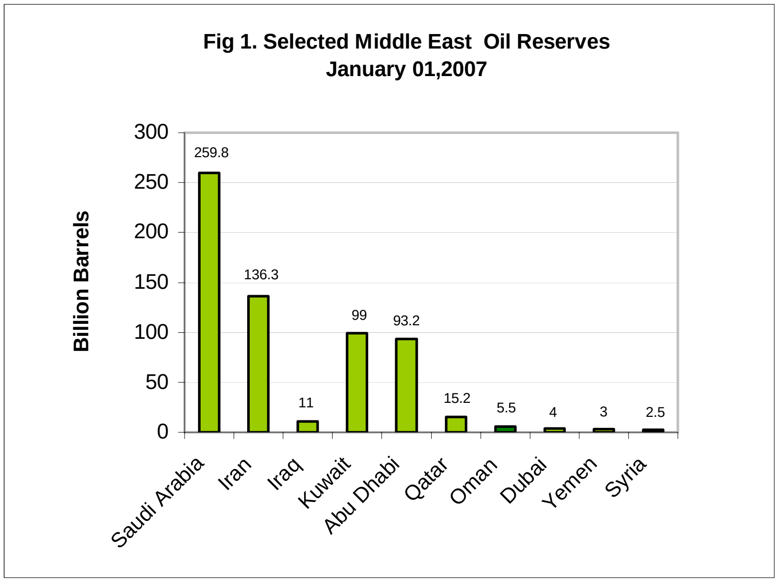


Fig 1. Selected Middle East Oil Reserves January 01,2007

Table 1 Oman's Natural Gas Production and Consumption

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Production (bn ft^3)	906	916	974	917	902	825	756	782	746	710	712
Consumption (bn ft^3)	50.51	53.40	52.54	54.72	57.23	58.43	63.91	66.00	69.10	82	100

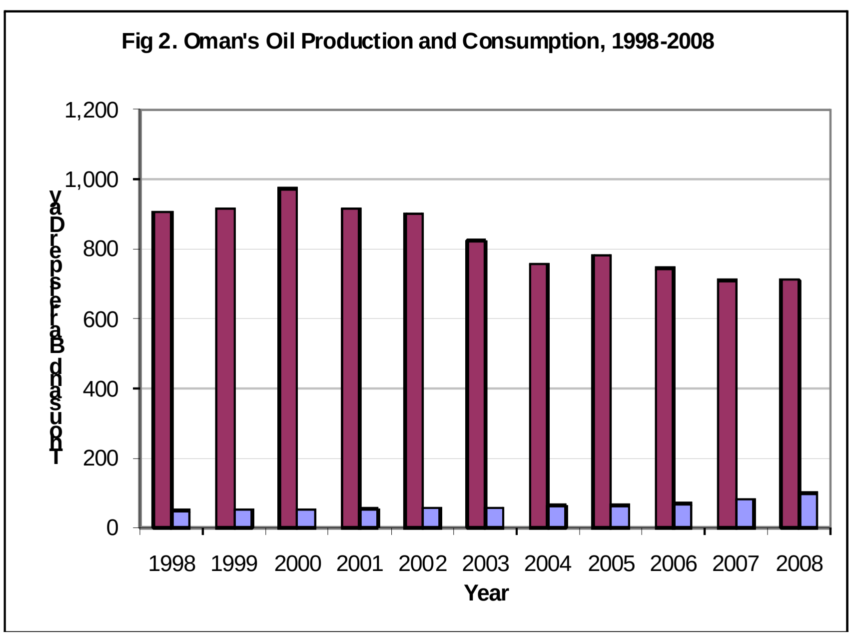


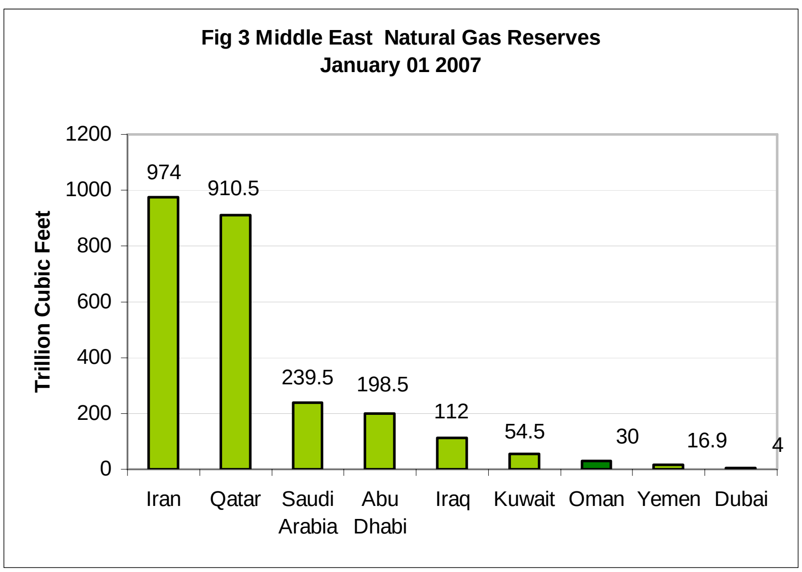
Fig 2. Oman's Oil Production and Consumption, 1998-2008

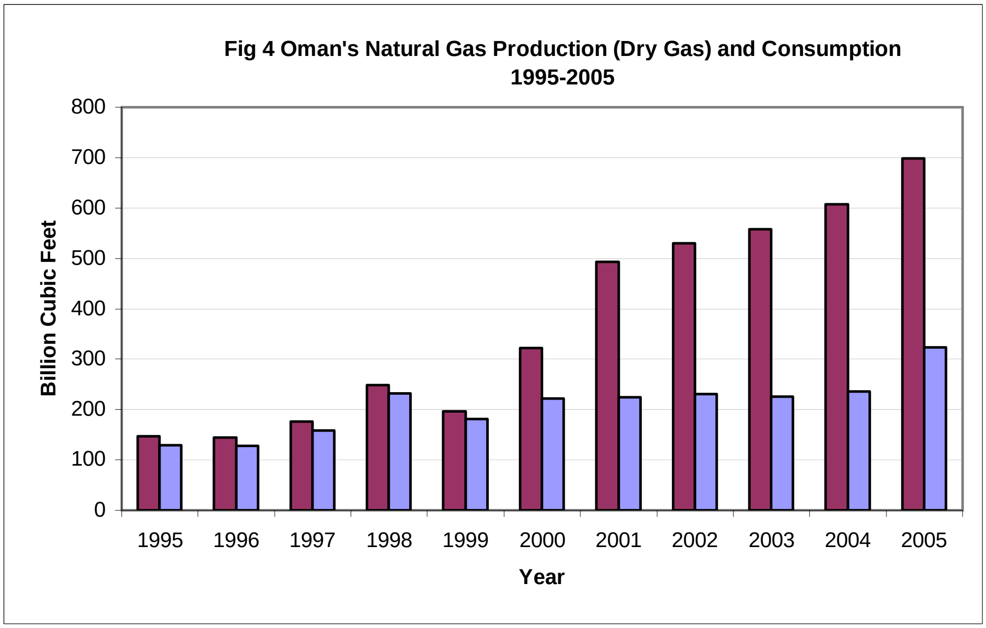
OMAN'S NATURAL GAS RESERVES

To counter the depletion of oil, natural gas production has been increased in Oman which has resulted in the expansion of natural-gas based industries, such as petrochemicals, power generation, and use of natural gas as feed stock for enhanced oil recovery projects. However, despite the recent rise in production, additional natural gas reserves have not been located as quickly as the Oman government had hoped. Some industry sources have speculated that, given the country's long-term liquefied natural gas (LNG) export obligations, natural as supplies may be overcommitted in Oman[1]. **Figure 3** shows the natural gas reserves of Middle East countries[1], which indicate Oman is having a reserve of 30.0 trillion cubic feet of natural gas. **Figure 4** indicates the Oman's Natural Gas Production and Consumption, which shows enormous growth in the production and slight increase in the consumption[1] .man's domestic energy consumption is supplied by natural gas and oil, reflecting the country's relative abundance of oil and natural gas reserves. **Figure 5** shows the total energy consumption in Oman based on oil and natural gas[1].

Table 2 Oman's Natural Gas Production and Consumption

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Production	147	145	176	248	197	322	493	530	558	607	699
Consumption	130	128	159	232	182	221	224	231	226	236	324





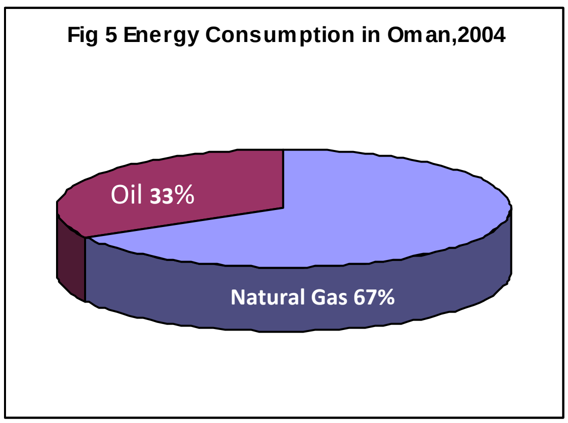


Fig.5: Original data source: Oil & Gas Journal, Jan 1-2007.

OMAN'S COAL RESERVES

An unexploited deposit, in excess of $120x10^6$ tonnes of coal, exists at Al-Kamil in the south-eastern Oman. The main seam in the Wadi Muswa area alone contains 24.6×10^6 tonnes. The coal in the Al-Kamil coalfield is classified as highly – volatile bituminous type. It has high sulphur content and moderate ash content: as such, it is probably more suitable for use as a fuel for electricity generation. The Wadi Muswa site has more significant deposits than the Wadi Fisaw site. The former deposit occurs in more than 30 seams in three zones. The main seam in the middle zone is the thickest and most laterally extensive. It will provide bulk of extractable reserves [3].

Saudi Arabia, the United Arab Emirates, Oman and Bahrain are all looking at the possibility of building coal-fired power plants, analysts and industry sources said. The region's electricity needs are soaring as petrodollars feed rapid economic expansion.

ALTERNATIVE ENERGY RESOURCES IN OMAN

Despite a decline in several fields, Oman's proven oil reserves continue to exceed 5 bn barrels, with petroleum development of Oman estimating that enhanced oil recovery [EOR] will add another 5 bn barrels of recoverable oil. Proven reserves of natural gas are estimated at 35 TCF and PDO, acting as a contractor for the government in gas E&P operations, aims to raise them to 50 TCF within the next 18 years. Oman has shifted to natural gas for domestic energy. With booming domestic demand for power, the hydrocarbon-rich Arabian Gulf countries including Oman are exploring the use of alternative and renewable energy resources including coal, nuclear, solar, wind and hydrogen. It may seem surprising that, with all the available hydrocarbon reserves, alternatives are figuring increasingly in Gulf region power planning. However this is displaying the classic wisdom: ‘In victory plan for defeat.’ In other words, when times are good, build resources against future uncertainty. Promoting alternative energy resources as an essential prerequisite for sustainable development of Oman economy is option to be explored. Fossil fuels take millions of years to make. We are using up the fuels that were made more than 300 million years ago before the time of the dinosaurs. Once they are gone they are gone. So, it's best to not waste fossil fuels. They are not renewable; they can't really be made again. We can save fossil fuels by conserving energy.

RENEWABLE ENERGY TECHNOLOGIES

Renewable energy covers a range of natural sources which are constantly renewed and therefore, unlike fossil fuels and uranium, will never be exhausted. Most of them derive from the effect of the sun and moon on the earth’s weather patterns. They also produce none of the harmful emissions and pollution associated with “conventional” fuels. Although hydroelectric power has been used on an industrial scale since the middle of the last century, the serious exploitation of other renewable sources has a more recent history.

SOLAR ENERGY

An assessment of the “magnitude” of solar radiation as an energy source depend on the geographical location, including local conditions such as cloudiness, turbidity, etc. For actual applications, it is often necessary to estimate the amount of radiation received by tilted or complexly shaped devices, and it is useful to look at relations which allow relevant information to be extracted from some basic measured quantities. For instance, radiation data often exist only for a horizontal plane, and a relation is therefore needed to predict the radiation flux on an arbitrarily inclined surface. In regions at high latitudes, directing solar devices towards the Equator at fairly high tilt angles actually gives an increase in incident energy relative to horizontally placed collectors. The following are the applications tapping solar radiation into useful energy.

PHOTOVOLTAIC (PV)

We can also change the sunlight directly to electricity using solar cells. Solar cells are also called photovoltaic cells - or PV cells for short - and can be found on many small appliances, like calculators, and even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made of silicon, a special type of melted sand. When sunlight strikes the solar cell, electrons (red circles) are knocked loose. They move toward the treated front surface (dark blue color). An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, like a wire, a current of electricity occurs between the negative and positive sides.

These individual solar cells are arranged together in a PV module and the modules are grouped together in an array. Some of the arrays are set on special tracking devices to follow sunlight all day long. The electrical energy from solar cells can then be used directly. It can be used in a home for lights and appliances. It can be used in a business. Solar energy can be stored in batteries to light a roadside billboard at night. Or the energy can be stored in a battery for an emergency roadside cellular telephone when no telephone wires are around. Some experimental cars also use PV cells. They convert sunlight directly into energy to power electric motors on the car.

Although the worldwide PV market has been growing at over 40% per annum in recent years, the contribution it makes to electricity generation is still very small. Development work is focused on improving existing modules and system components and developing new types of cells in the thin-film sector and new materials for crystalline cells. It is expected that the efficiency of commercial crystalline cells will improve by between 15 and 20% in the next few years, and that thin-film cells using less raw material will become commercially available. The learning factor for PV modules has been fairly constant over a period of 30 years at around 0.8, indicating a continuously high rate of technical learning and cost reduction. Assuming a globally installed capacity of 2,000 GW in 2050, and a decrease in the learning rate after 2030, we can expect that electricity generation costs of around 5-9 cents/kWh will be possible by 203010. Compared with other technologies for utilizing renewable, photovoltaic power must therefore be classified as a long-term option. Its importance derives from its great flexibilityand its enormous technical potential for rural electrification for the 2 billion people currently having no access to electricity.

CONCENTRATING SOLAR POWER PLANTS

Solar thermal 'concentrating' power stations can only use direct sunlight and are therefore dependent on high irradiation locations. North Africa, for example, has a technical potential which far exceeds local demand. The various solar thermal technologies (parabolic trough, power towers and parabolic dish concentrators) offer good prospects for further development and cost reductions. One important objective is the creation of large thermal energy reservoirs in order to extend the Operating time of these systems beyond the sunlight period. Owing to the small number of Concentrating Solar Power (CSP) plants built to date, it is difficult to arrive at reliable learning factors for this sector. Energy Assessment expects solar thermal electricity generation will enjoy a dynamic market growth similar to the wind industry, but with a time lag of 20 years. Depending on the level of irradiation and mode of operation, electricity generation costs of 5-8 cents/kWh are expected. This presupposes rapid market introduction in the next few years. And it doesn't get much more remote than the top of a mountain range in the Middle Eastern country of Oman, where Perth, Australia-based Solar Sales, recently completed a series remote solar photovoltaic (PV) applications for local telecommunications company Omantel.

The solar arrays provide power to remote communications towers that increase the local carrier's mobile phone coverage network in several regions around a mountain range south of the capital, Masqat.Oman occupies the southeast corner of the Arabian Peninsula and borders Saudi Arabia and the United Arab Emirates in the West and the Republic of Yemen in the South. With a land area of approximately 309,500 km2 it is the third largest country in the Arabian Peninsula, and roughly the size of the U.S.state of Kansas. Omantel chose eight very remote locations, of which seven were only accessibly by helicopter. Solar Sales had to design a standalone solar power system for each location which took several factors into consideration including microwave power requirements, battery types and sizes, frame and foundation design and expansion possibilities. While designing the solar systems for these remote locations was no easy feat, simply getting all the equipment to the sites was the greatest challenge. In the 1890s solar water heaters were being used all over the United States. They proved to be a big improvement over wood and coal-burning stoves. Artificial gas made from coal was available too to heat water, but it cost 10 times the price we pay for natural gas today. And electricity was even more expensive if you even had any in your town.

SOLAR THERMAL COLLECTORS FOR HEATING AND COOLING

Small solar thermal collector systems for water and auxiliary heating are well developed today and used for a wide variety of applications. By contrast, large seasonal heat reservoirs that store heat from the summer until it is needed in the winter are only available as pilot plants. Only by means of local heating systems with seasonal storage would it be possible to supply large parts of the low temperature heat market with solar energy. Crucial factors for market launch will be low storage costs and an adequate usable heat yield. Data for the European collector market show a learning factor of nearly 0.90 for solar collectors, which indicate a relatively well developed system from a technological point of view. By contrast, the construction of seasonal heat reservoirs is expected to show a long term cost reduction of over 70%. Depending on the configuration of the system, it will be possible in the long term to achieve solar thermal costs of between 4 and 7 cents/kW.

BIOMASS ENERGY

Biomass is matter usually thought of as garbage. Some of it is just stuff lying around, dead trees, tree branches, yard clippings, left-over crops, wood chips, bark and sawdust from lumber mills. It can even include used tires and livestock manure. Recycling biomass for fuel and other uses cuts down on the need for "landfills" to hold garbage.

The crucial factor for the economics of biomass utilization is the cost of the feedstock, which today ranges from a negative cost for waste wood (credit for waste disposal costs avoided) through inexpensive residual materials to the more expensive energy crops. The resulting spectrum of energy generation costs is correspondingly broad. One of the most economic options is the use of waste wood in steam turbine combined heat and power (CHP) plants. Gasification of solid bio fuels, on the other hand, which opens up a wide range of applications, is still relatively expensive. In the long term it is expected that favorable electricity Production costs will be achieved by using wood gas both in micro CHP units (engines and fuel cells) and in gas-and-steam power plants. Great potential for the utilization of solid biomass also exists for heat generation in both small and large heating centers linked to local heating networks. Converting crops into ethanol and ‘bio diesel’ made from rapeseed methyl ester (RME) has become increasingly important in recent years, for example in Brazil and the USA. Processes for obtaining synthetic fuels from biogenic synthesis gases will also play a growing role. A great potential for exploiting modern technologies exists in Latin America, Europe and the Transition Economies either in stationary appliances or the transport sector. For these regions it is assumed that in the long term 60% of the potential for biomass will come from energy crops, the rest from forest residues, industrial wood waste and straw. In other regions, like the Middle East, South Asia or China, the additional use of biomass is restricted, either due to a generally low availability or already high traditional use. For the latter, using more efficient technologies will improve the sustainability of current biomass use.

GEOTHERMAL ENERGY

Geothermal energy has long been used worldwide for supplying heat, whilst electricity generation is limited to a few sites with specific geological conditions. Further intensive research and development work is needed to speed up progress. In particular, the creation of large underground heat-exchange surfaces (HDR technology) and the improvement of heat-and-power machines with Organic Rankine Cycle (ORC) must be optimized in future projects. As a large part of the costs for a geothermal power plant come from deep drilling, data from the oil sector can be used, with learning factors observed there of less than 0.8. Assuming a global average market growth for geothermal power capacity of 9% per year until 2020, reducing to 4% beyond 2030, the result would be a cost reduction potential of 50% by 2050.Thus, despite the present high figures (about 20 cents/kWh), electricity production costs – depending on payments for heat supply – are expected to come down to around 6-10 cents/kWh in the long term. Because of its non-fluctuating supply, geothermal energy is considered to be a key element in a future supply structure based on renewable sources.

OCEAN ENERGY

The world's ocean may eventually provide us with energy to power our homes and businesses. Right now, there are very few ocean energy power plants and most are fairly small. But how can we get energy from the ocean? There are three basic ways to tap the ocean for its energy. We can use the ocean's waves, we can use the ocean's high and low tides, or we can use temperature differences in the water.

TIDAL POWER

Kinetic energy (movement) exists in the moving waves of the ocean. That energy can be used to power a turbine. In this simple example, to the right, the wave rises into a chamber. The rising water forces the air out of the chamber. The moving air spins a turbine which can turn a generator. When the wave goes down, air flows through the turbine and back into the chamber through doors that are normally closed. This is only one type of wave-energy system. Others actually use the up and down motion of the wave to power a piston that moves up and down inside a cylinder. That piston can also turn a generator. Most wave-energy systems are very small. But, they can be used to power a warning buoy or a small light house. Another form of ocean energy is called tidal energy. When tides come into the shore, they can be trapped in reservoirs behind dams. Then when the tide drops, the water behind the dam can be let out just like in a regular hydroelectric power plant.

Tidal energy has been used since about the 11^{th} Century, when small dams were built along ocean estuaries and small streams. The tidal water behind these dams was used to turn water wheels to mill grains. In order for tidal energy to work well, you need large increases in tides. An increase of at least 16 feet between low tide to high tide is needed. There are only a few places where this tide change occurs around the earth. Some power plants are already operating using this idea. One plant in France makes enough energy from tides (240 megawatts) to power 240,000 homes. This facility is called the La Rance Station in France. It began making electricity in 1966. It produces about one fifth of a regular nuclear or coal-fired power plant. It is more than 10 times the power of the next largest tidal station in the world; the 17 megawatt Canadian Annapolis station Tidal power can be harnessed by constructing a dam or barrage across an estuary or bay with a tidal range of at least 5 meters. Gates in the barrage allow the incoming tide to build up in a basin behind it. The gates then close so that when the tide flows out the water can be channeled through turbines to generate electricity. Tidal barrages have been built across estuaries in France, Canada and China but a mixture of high cost projections coupled with environmental objections to the effect on estuarial habitats has limited the technology’s further expansion.

WAVE AND TIDAL STREAM POWER

In wave power generation, a structure interacts with the incoming waves, converting this energy to electricity through a hydraulic, mechanical or pneumatic power take-off system. The structure is kept in position by a mooring system or placed directly on the seabed/seashore. Power is transmitted to the seabed by a flexible submerged electrical cable and to shore by a sub-sea cable. Wave power converters can be made up from connected groups of smaller generator units of 100 – 500 kW, or several mechanical or hydraulically interconnected modules can supply a single larger turbine generator unit of 2 – 20 MW.The large waves needed to make the technology more cost effective are mostly found at great distances from the shore, however, requiring costly sub-sea cables to transmit the power. The converters themselves also take up large amounts of space. Wave power has the advantage of providing a more predictable supply than wind energy and can be located in the ocean without much visual intrusion. There is no commercially leading technology on wave power conversion at present. Different systems are being developed at sea for prototype testing. These include a 50 kW Power Buoy floating buoy device installed in Hawaii, a 750 kW Polaris device, with linked semi submerged cylindrical sections, operating in Scotland, a 300 kW underwater tidal current turbine operating in south-west England, a 150 kW seabed-mounted Stingray, also using tidal currents, and a 500 kW coastline wave energy generator operating on the island of Islay, Scotland. Most development work has been carried out in the UK.

GEOTHERMAL ENERGY

Geothermal Energy has been around for as long as the Earth has existed. "Geo" means earth, and "thermal" means heat. So, geothermal means earth-heat. Below the crust of the earth, the top layer of the mantle is a hot liquid rock called magma. The crust of the earth floats on this liquid magma mantle. When magma breaks through the surface of the earth in a volcano, it is called lava. For every 100 meters you go below ground, the temperature of the rock increases about 3 degrees Celsius. Or for every 328 feet below ground, the temperature increases 5.4 degrees Fahrenheit. So, if you went about 10,000 feet below ground, the temperature of the rock would be hot enough to boil water. Deep under the surface, water sometimes makes its way close to the hot rock and turns into boiling hot water or into steam. The hot water can reach temperatures of more than 300 degrees Fahrenheit (148 degrees Celsius). This is hotter than boiling water (212 degrees F / 100 degrees C). It doesn't turn into steam because it is not in contact with the air. When this hot water comes up through a crack in the earth, we call it a hot spring, like Rustak ht water springs names in an around Oman.

GEOTHERMAL ELECTRICITY

Hot water or steam from below ground can also be used to make electricity in a geothermal power plant. In California, there are 14 areas where we use geothermal energy to make electricity. The red areas on the map show where there are known geothermal areas. Some are not used yet because the resource is too small, too isolated or the water temperatures are not hot enough to make electricity.

The main spots are:

- The Geysers area north of San Francisco
- In the northwest corner of the state near Lassen Volcanic National Park
- In the Mammoth Lakes area - the site of a huge ancient volcano
- In the Coso Hot Springs area in Inyo County
- In the Imperial Valley in Southern California.

Some of the areas have so much steam and hot water that it can be used to generate electricity. Holes are drilled into the ground and pipes lowered into the hot water, like a drinking straw in a soda. The hot steam or water comes up through these pipes from below ground. A geothermal power plant is like in a regular power plant except that no fuel is burned to heat water into steam. The steam or hot water in a geothermal power plant is heated by the earth. It goes into a special turbine. The turbine blades spin and the shaft from the turbine is connected to a generator to make electricity. The steam then gets cooled off in a cooling tower. California's geothermal power plants produce about one-half of the world's geothermal generated electricity. The geothermal power plants produce enough electricity for about two million homes.

GEOTHERMAL / GROUND SOURCE HEAT PUMPS

Though it gets much hotter as we go deep below ground, the upper layer of the earth close to the surface is not very hot. Almost everywhere across the entire planet, the upper 10 feet below ground level stays the same temperature, between 50 and 60 degrees Fahrenheit (10 and 16 degrees C). If you've ever been in a basement of a building or in a cavern below ground, the temperature of the area is almost always cool. A geothermal or ground source heat pump system can use that constant temperature to heat or cool a building. Pipes are buried in the ground near the building. Inside these pipes a fluid, like the antifreeze in a car radiator, is circulated. In winter, heat from the warmer ground goes through the heat exchanger of a heat pump, which sends warm air into the home or business. During hot weather, the process is reversed. Hot air from inside the building goes through the heat exchanger and the heat is passed into the relatively cooler ground. Heat removed during the summer can also be used to heat water.

CONCLUSIONS

Renewable energy technologies vary widely in their technical and economic maturity, but there are a range of sources which offer increasingly attractive options. These sources include wind, biomass, photovoltaic, solar thermal, geothermal, ocean and hydroelectric power. Their common feature is that they produce little or no greenhouse gases, and rely on virtually inexhaustible natural sources for their “fuel”. Some of these technologies are already competitive. Their economics will further improve as they develop technically, as the price of fossil fuels continues to rise and as their saving of carbon dioxide emissions is given a monetary value. At the same time there is enormous potential for reducing our consumption of energy, while providing the same level of energy ‘services’. This study details a series of energy efficiency measures which together can substantially reduce demand in industry, homes, business and services. The solution to our future energy needs lies in greater use of renewable energy sources for both heat and power.

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