Alternative Sources of Energy

David Kennedy
Technological University Dublin, david.kennedy@tudublin.ie

ALTERNATIVE SOURCES OF ENERGY

David M. Kennedy
Mechanical Engineering
Dublin Institute of Technology
Dublin 1. Ireland

Abstract
Ireland relies on imports of fossil fuels for up to 83% of its energy needs and this statistic is relatively common in other European countries. Apart from the high import costs and pollutions associated with fossil fuels and the need to meet new targets in terms of CO_2 emissions, energy security is essential. This paper provides an overview and outline of the different alternative energy sources available for use either at domestic or on large scale production, some of which are established and others less likely to succeed in our climate. Some of the alternative energy sources such as wind and wave are gaining acceptance for Irish Climatic conditions and their growth rate and associated costs are outlined. The development from petrol to Liquid Petroleum Gas (LPG) to Hydrogen as a green fuel is presented. The paper will also outline how other countries are dealing with their energy needs through renewable and natural energy sources.

Keywords: Renewable Energy, Solar, Photovoltaic, Natural Light pipes

1. Introduction

With or without a shortage of traditional energy fuels such as oil, coal or gas, there is a major need to develop secure and sustainable sources of energy. The most basic ingredient in economic growth is energy and very little happens without it. Global demand for energy is set to double over the next 25 years and since it took the world economies 125 years to use the first trillion barrels of oil, we'll use the next trillion in 30 years. We are a power-hungry society, using largely fossil fuels, to move cars and trains, heat and cool buildings and provide electricity for equipment of all types. We pay for this through the price per barrel, smog, pollution and greenhouse gasses. 35 years ago it was thought that almost every energy source was about to run out

After the oil crisis of 1973, Energy industries looked to renewable energies which in theory could never run out. However after 1973 oil did not run out, huge reserves of Natural gas were discovered. Coal reserves in the UK for instance were 1,000 times the annual consumption in UK. Nuclear expansion proceeded (a six fold increase) until Chernobyl disaster.

Car sales in Russia grew 60% in 2007 and in China and Brazil, car sales grew by 20% and 30% respectively while the sales of small vehicles on growth in Europe

86 million barrels of oil are consumed each day worldwide while the UK consumes 1.7 million barrels of oil a day and The United States consumes 170 billion gallons of gasoline and diesel fuel annually. In light of all this development, OPEC presidents predict that oil prices will rise to $200 per barrel [1]. 86 million barrels of oil are consumed each day worldwide, while the UK consumes 1.7 million barrels of oil a day. The United States consumes 170 billion gallons of gasoline and diesel fuel annually. The main concern for the environment is that world global temperatures are rising, ice caps are melting and sea levels will rise as a result. The Greenhouse effect is primarily blamed for this and the emission of CO_2 is seen as main culprit. Other experts however have reported that global temperatures have not increased significantly since the Kyoto agreements (1997) and over the last 5 years global temperatures have not changed. It has been reported that the average global temperature rose by 0.6^{o}C during the last century and is forecast to rise by 3^{o}C this century European annual mean temperatures increased by 0.3 – 0.6˚C since 1900, with 1998 the warmest on record. The primary reason for countries having their own sustainable energy supply is that it is predictable, there is less pollution, it can create employment locally, it is sensible economics, it generates savings on imports, prevents manmade disasters, makes use of environmentally friendly natural resource and areas such as wave and wind energy to Ireland are as good as Oil and Gas to the OPEC countries. CO_2 and CH4 are responsible for 70% and 24% of "greenhouse effect". CO_2 contributes to Ocean acidity through formation of Carbonic acid as outlined in tests consisting of 24,000 pH readings over an 8 year period. Chlorofluorocarbons (CFCs) used in the built environment contribute some 15% to greenhouse effect. Hydro chlorofluorocarbons (HCFCs) that replaced CFCs can have as much as 4038 times the global warming potential of CO_2, depending on their Ozone Depletion Potential. From a construction point of view, the concrete used in an average 3 bed semi-detached house produces approximately 20 tons of $C0_2$ in construction.

In the US, the annual business losses stemming from power interruption are estimated to be $70bn.

2. Developments in Renewable and sustainable energy

2.1 Renewable and Sustainable Energy Supplies

Renewable and sustainable energy supplies can be defined as environmentally desirable unlike fossil & fission fuels. Typical examples include the following:

- i Wind power
- ii Wave and Tidal power
- iii Heat pumps
- iv Solar power
- v Biofuels
- vi Fuel Cells

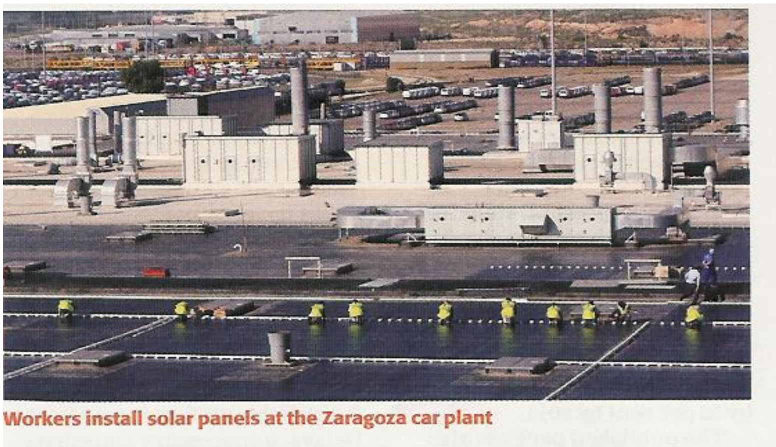
Renewable energies are theoretically carbon free and should be economically viable, not just because of global warming.

2.2 Worldwide developments

In 2007, the USA became world's second largest generator of electricity by wind power after Germany. The combined capacity of the five largest wind power states in America is over 10,000MW. At end of 2007, the US had 3,400MW of solar power including 750MW of PV, Including Alaska, the USA ranks first for Solar resources followed by Germany, Japan and Spain. Up to 5,000MW of Solar is planned for the USA by 2014(1.3M homes by 2014) and the state of California is heading for 20% Solar generated power by 2010.

General Motors (GM) is installing the world's largest rooftop solar power station at a car assembly plant in Spain (Zaragoza). This consists of 85,000 panels covering an area of 183,000 m^2. This will produce a peak output of 12MW and generate 15 M kWh annually for the local grid. This is equivalent to 4,575 households with an average annual consumption of 3,300kWh. Figure 1. shows an example of this development.

Switzerland's most powerful PV system has been installed on the river Rhone in Geneva. This provides a nominal power of 1MW. Up to 6,000 monocrystalline solar modules covering an area of 16,000 sq metres and capable of generating 1GWh of solar electricity each year is the potential output at a capital cost of €4.8M. In support of this development, four Swiss soccer clubs have installed solar systems on stadium roofs to generate 1,000,000 kWh of energy per year. Ireland with its temperate climate, lack of heavy industry and green energy potential is well positioned to capitalise on sustainable energy sources such as wind and wave. In the In UK for instance, 80% of energy comes from Fossil Fuels generating a high CO_2 footprint. In France on the other hand, 20% of the energy needs come from fossil fuels, generating a low CO_2 footprint.



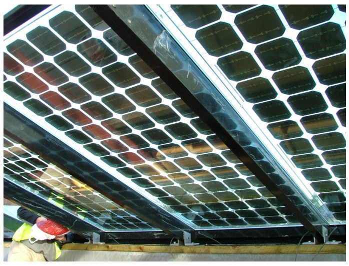


Figure 1. General Motors Photo-Voltaic plant in Zaragoza, Spain.

2.3 Solar Energy developments

In 212 b.c. it was reported that Archimedes Ignited Roman ships by reflecting sunlight through the use of mirrors. During 1695 and 1774 Diamond and Platinium was melted using focused sunlight and Solar furnaces respectively. During 1950, Felix Trombe designed a solar array to match the suns temperature (5,538^{o}C) and in 1954 the development of the first successful silicon solar cell was achieved, followed in 1980 by the development of thin film solar cells. Photovoltaics (PVs') generate electricity without emissions, no moving parts, highly reliable and need no external fuel. They are typically used to charge batteries, power circuits directly, detect sunlight, detect light from LED, lamps etc. and power satellites, remote devices, sea buoys and parking meters. Their main disadvantages are costs (30 to 40 c per kWh versus 10c standard.) and their efficiency is less than 30% with silicon units less than 15% efficient. The total radiated power from the sun is 3.83x1023 kW. However only a small fraction of this energy is radiated to earth. The Solar constant at the top of the earth's atmosphere is 1368 W/m2 and due to cloud, and local atmosphere etc. less energy is absorbed at ground level. Figure 2. shows an example of a simple Solar system for generating hot water while Figure 3. shows the free availability of geothermal energy in Iceland. Figure 4. shows a typical wind farm in Ireland using 1MW generators. Other examples of renewable and sustainable energy sources are given in Table 1.

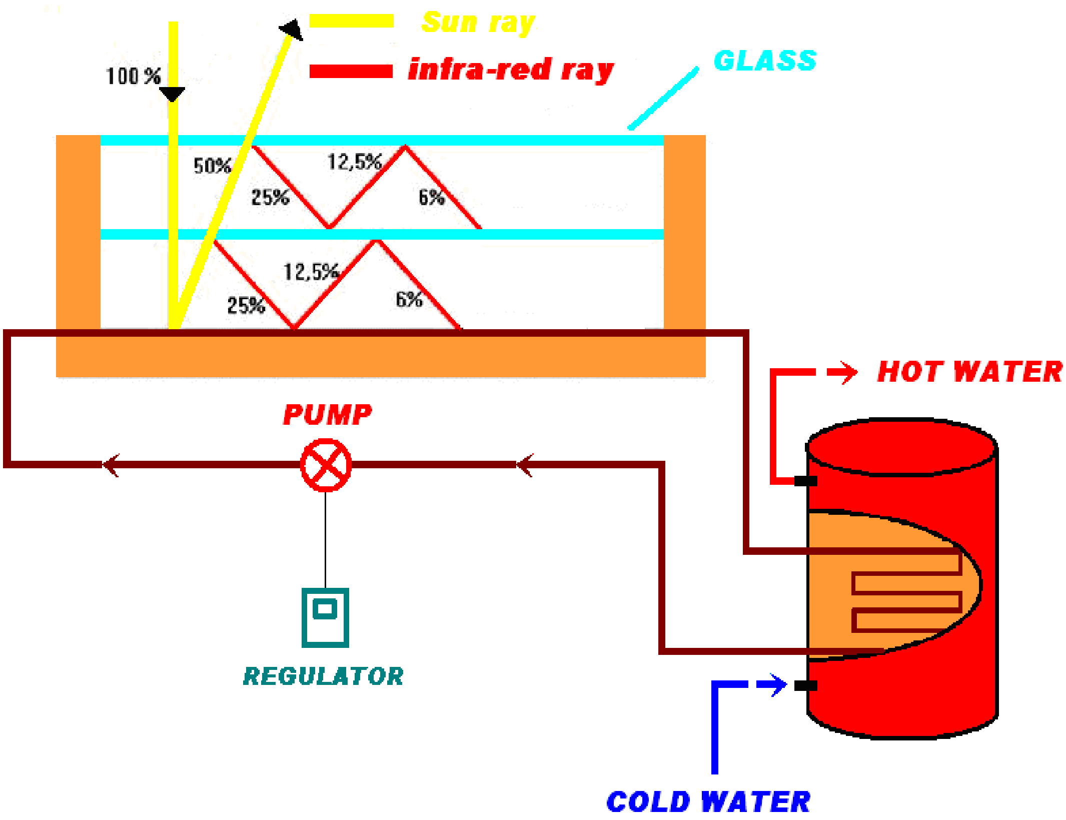


Figure 2. Basic Solar energy system.

Figure 3. Geothermal: surface and subsurface

Figure 4. Wind power generation

	Wind power: Constructing windmills and wind farms to harness the wind on both land and at sea.
	Waste conversion. Landfill gas, Production of Methane, Typical house hold waste, agricultural waste and industrial waste conversion.
	Solar power: Solar, PV and mirrors to harness the sun's radiation. Solar ponds.
	Thermal insulations: Sustainable methods
	Wave power: Generating electricity from the natural energy of the oceans, Tidal power, wave and current generators, Tidal Barrages,
	Fuel Cell Technology; CHP; Various types
	Tidal power: Harnessing regular motion of the tides by barrages or tidal water wheels
	Natural Lighting for buildings, tunnels, factories and homes.
	Biofuels: converting plants(sugar cane & beet, corn, soya beans, flax, rape, camilina etc) to fuel for transport, aircraft and power stations
	Hydrogen production and applications for motor transport
	Heat pumps: Transferring heat from the ground to a building etc.

Table 1. Common types of renewable energy

2.4 Pressure Retarded Osmosis

If a solvent is separated from its solution by a semi permeable membrane, the solvent has a tendency to pass through the membrane, diluting the solution, caused by osmosis. This flow through a membrane against an opposing pressure across the membrane is called pressure retarded osmosis. An example f this is shown in Figure 5. The osmotic power depends on the rate at which the solution is diluted.
The power is given as follows:

Power = k(Л-P)P and the maximum power is equal to $k*Л^2/4$

Where; Л = Osmotic pressure and
k= membrane permeability (10-250 m3/m^2-bar sec)

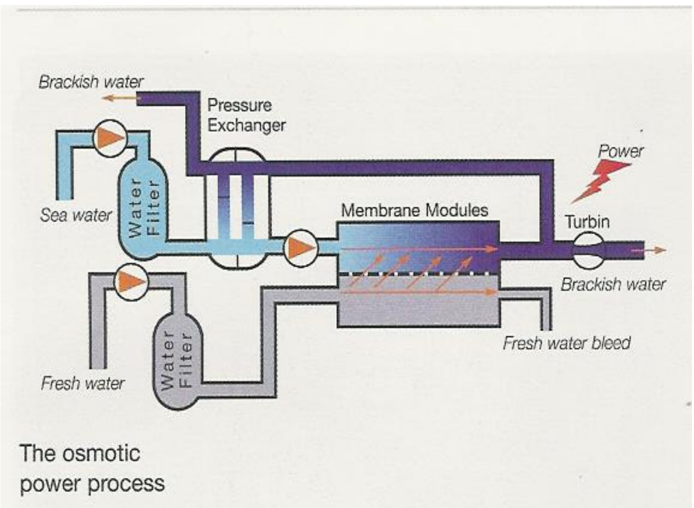


Figure 5. Pressure Retarded Osmosis System

2.5 Hydrogen adoption and Electric vehicles

To date Compressed Natural Gas (CNG) Kits have operated successfully in motor transport. This has followed the successful application of Liquid Petroleum Gas (LPG0 powered vehicles. More recent developments has led to the conversion to Hydrogen fuelled engines. By replacing the CNG tank with a Hydrogen tank, this is feasible and tests have been undertaken on a number of vehicles to date including a conventional Nissan Almera.
The key advantage of this is that a new car for this to work is not required. The main expense is the hydrogen tank. Other developments include the Ford 4X4 Edge and Ford Fusion Hydrogen 999, giving a power of 250 bhp and torque of 340 lb ft. This vehicle uses 4.5kg of hydrogen @ 350 Bar and has a range of 225 miles or 300 miles with 700bar storage, with a top speed: 88mph. Making Hydrogen from Natural Gas is no cleaner than a conventional car. However hydrogen can be produced from Nuclear Energy, Electrolysers via Photovoltaics and in Countries such as Iceland, Norway and Denmark, is produced from electricity generated from wind and wave technology. Hydrogen as a fuel is safer than petrol because it rapidly dissipates if it leaks. The British Prime Minister, Gordon Browne has pledged £90M to make Britain the European Capital for Electric Cars for the next generation of vehicles, while Toyota are preparing a petrol-electric (lithium–ion batteries) hybrid for the Japanese, US and European market for 2010. The standard Toyota Prius uses a conventional nickel-metal-hydride battery and the new technology is an advance on this. The Dyson corporation is also currently investigating the development of electrical vehicles fuelled by PV panels. Three examples of such developments are shown in Figure 6.

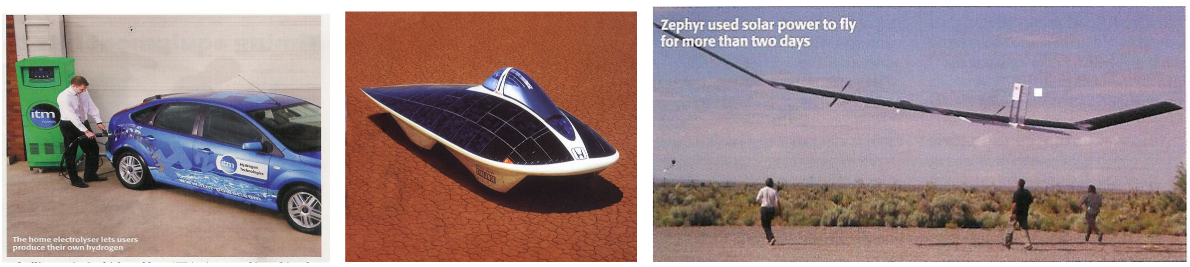


Figure 6. Electrolyser fuelled Hydrogen Car. PV Care and PV solar powered flight.

2.6 Bio fuels and LPG

Ethanol is the most widely used biofuel and over 1.5 Billion gallons are added to gasoline in the U.S. each year. It increases octane and improves emissions as a blended fuel with gasoline. The USA plan to generate 25% of its fuel from Bio materials by 2025 while Europe has targeted 10% of fuels from bio by the year 2020. Currently however up to 25% of America's corn harvest is converted to ethanol (2008) assisted by 51cent subsidy on each gallon. This subsidy has made the production of ethanol very attractive to farmers but may have a negative impact on food production. Other raw materials include Methanol, Waste Cooking oil, Camelina Sativa, Rapeseed, and Beef Tallow.
Camelina Sativa has a similar yield to rapeseed, grows well on poor soil and is cheaper to produce than rapeseed oil. One of the drawbacks of biodiesel include solidification at low temperatures and it is normally blended with petroleum diesel to operate in vehicles, taking account of engine modification requirements. Figure 7. shows a typical process for converting seed to biodiesel. The glycerol produced can be used for pharmaceutical applications provided there is enough supply.
For Liquid Petroleum Gas, gases such as Propane and Butane are a minority of transport fuels to date. The CO_2 emissions with LPG are estimated to produce 12% less than a gasoline vehicle based on Tank-To-Wheel, or tailpipes, emissions. For example, an originally gasoline-fuelled car emitting 148 g/km would emit 130 g/km at the tailpipe on LPG when running on LPG and therefore the 4.6 million LPG vehicles, supported by 22,500 stations, in Europe equates to ~ 1.4 million tons of CO_2 savings each year. Although the market for LPG vehicles reduced considerably in Ireland, other EU countries have a thriving market. In

Germany for instance, LPG vehicles numbered 65,000 in 2005, 125,000 in 2006 and 190,000 in 2007. Projections are for 430,000 by 2010 and 1,000,000 by 2015. LPG has substantial reserves due to its dual origins: 66% from gas field extraction and 34% from crude oil refining

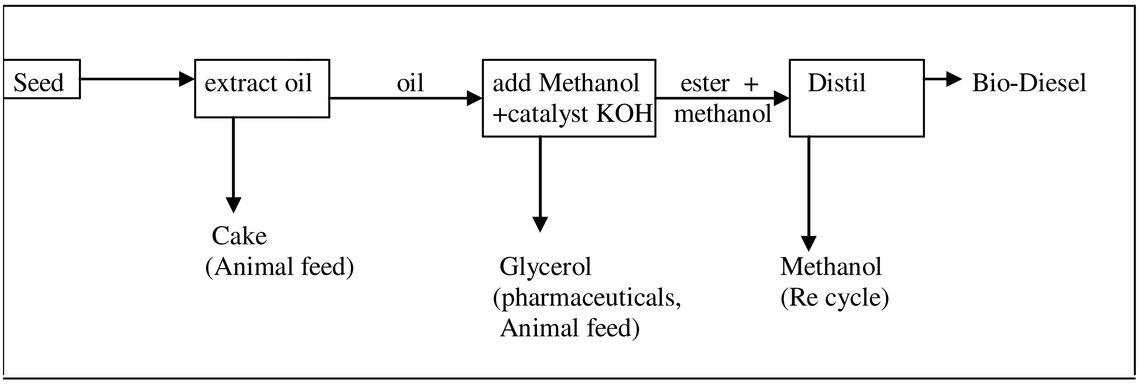


Figure 7. Biodiesel production from vegetable oil seed such as Rape Seed or Camelina Sativa.

2.7 Fuel Cells

Fuel Cells convert Hydrogen to a viable and sustainable electrical energy. Hydrogen Fuel Cells generate a current by passing hydrogen and Oxygen over either side of a membrane. This allows an exchange of protons and causes electrons to flow. The by products are water and heat energy which can be used for heating purposes. Approximately 50%of the hydrogen energy is converted to electricity in the process. The main types of Fuel Cells include:

Proton Exchange Membrane (PEM)
Phosphoric Acid Fuel Cells (PAFC)
Molten Carbonate Fuel Cells (MCFC)
Zinc-Air Fuel Cells (ZAFC)
Regenerative Fuel Cells (RFC)
Alkaline Fuel Cells (AFC)
Direct Methanol Fuel Cells (DMFC)
Solid Oxide Fuel Cells (SOFC)
Protonic Ceramic Fuel Cell (PCFC)

Recent developments in fuel cells include signage, lighthouses, and transport applications in motor bikes, cars and busses for urban use.

2.8 Bio Gas

Landfill gas contributes the largest proportion of renewable energy in the UK. One such application includes Heathfield landfill which opened in 1998 and due to close in 2016, burying 9M tonnes of refuse and currently potential to generate up to 6MW of electricity. Organic matter breaks down in the absence of oxygen, anaerobic digestion occurs, producing methane, CH_4. However CH_4 is 21 times more potent than Carbon as a greenhouse gas. The main energy of biogas comes from methane (37.78 MJ/m^3). Following scrubbing the methane content can be brought to 97% and with an energy value of 36.6MJ/m^3 is equivalent to 1 litre of petrol. In the Linkoping Biogas plant in Sweden, up to 99,000tpa of waste is treated and the produced CH_4 is used to fuel 56 buses and 360 other vehicles. The Biogas replaces 2,000000 litres of diesel fuel. By using Biogas systems efficiently, the waste products of a city may typically fuel the bus fleet of the city. In Ireland, aagricultural wastes are the main source of biomass as shown in Figure 8.

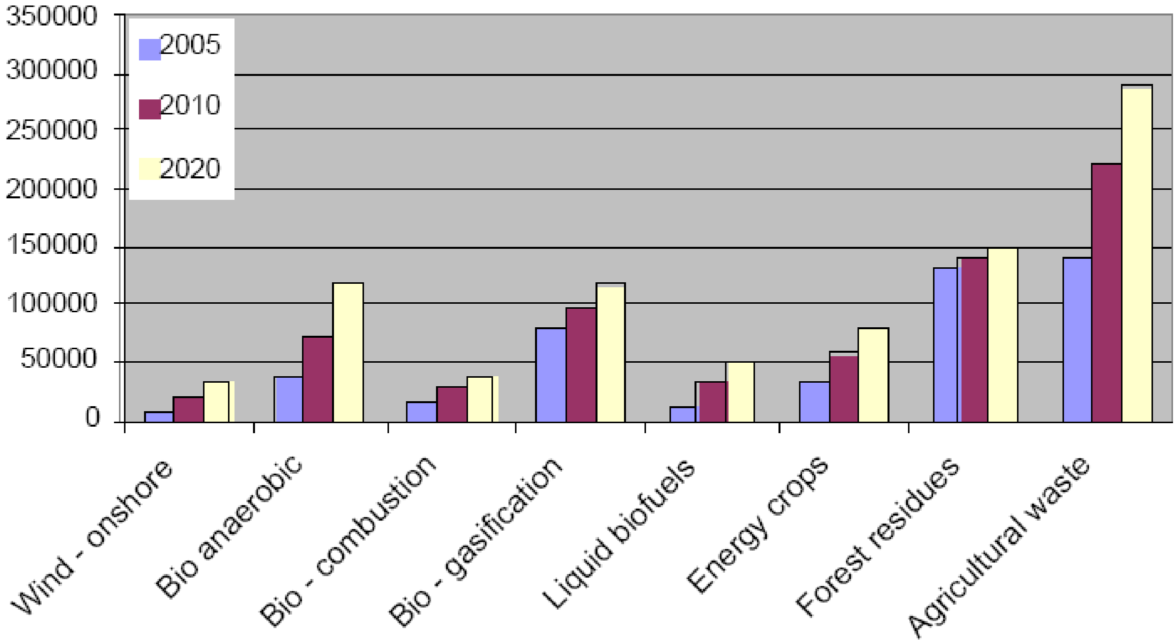
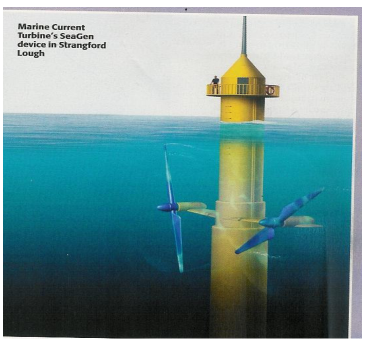


Figure 8. Sources of Bio gas production in Ireland 2005 to 2020.

2.9 Tidal, wave energy and solar ponds

In May 2008, the worlds first commercial tidal turbine was installed in Strangford Lough, in Northern Ireland by Marine Current Turbines. This is designed to produce 1.2 MW of electricity and when connected to the National Grid, will provide power to 1,000 homes. Also in May 2008, Open Hydro connected a demonstration tidal power rig to the UK grid of 250kW in Orkney. Wave power is predictable and Ireland is well positioned to harness this energy. Other applications include Tidal Barrages which are very rare and require a 5m head of water for worthwhile electricity. Examples of these are shown in Figure 9. and Figure 10.



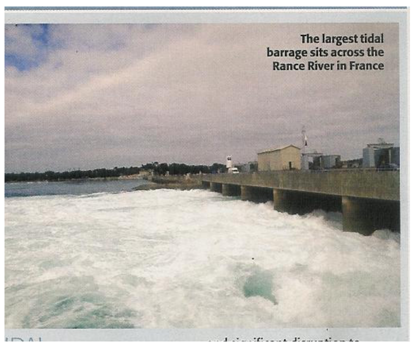


Figure 9. Tidal Turbine In Ireland **Figure 10. Tidal Barrage in France**

Solar pond technology inhibits convection by dissolving salt into the base layer of a pond. The salt concentration increases with depth, forming a salinity gradient. Solar ponds generally utilize a 1- 2 m salinity gradient and operate at moderately high temperatures. The salinity gradient prevents dense hot water rising from the bottom. The sunlight which reaches the bottom of the pond remains entrapped there and the useful thermal energy is then withdrawn from the solar pond in the form of hot brine. Even when covered with a sheet of ice and surrounded by drifts of snow, the El Paso (Mexico) Solar Pond's lower zones produce temperatures of 154°F which is hot enough to generate electricity. Application include generating heat and electricity, water desalination, space heating thermal energy storage, heating for greenhouses and livestock buildings

3.0 Conclusions

Climate change could cost the world at least 5% of GDP each year and if more dramatic predictions come to pass, the cost could be more than 20%. Natural cycles and sinks are not absorbing atmospheric carbon as fast as we are releasing it as GHGs and atmospheric CO_2 concentrations have increased by almost 100 ppm since their pre-industrial level, reaching 379 ppm in 2005. The benefits of strong, early action considerably outweigh the costs.

It is estimated that each tonne of CO_2 emitted causes damages worth at least $85, but emissions can be cut at a cost of less than $25 per tonne. The annual emissions of Ireland for 2007 are 70.1 Million tonnes CO_2 while the Kyoto Targets for Ireland are 62.8 Mt for the years 2008-2012. This is 13% above the 1990 base. The EU Targets for Ireland under the 20-20 strategy include emissions reduction of 20% (on 2005 base), increase renewables from 3.1% to 16% and use energy in a smarter way in all applications. The Introduction of Low energy Buildings, combined-cycle power plants, efficient lighting should enhance this.

Renewables are not load following like traditional power generation. They are intermittent, variable in production, often distant from loads, and not dispatchable.

In light of the development in renewable and sustainable energy, the energy storage sector is central to the full integration of wind energy generation and Carbon Capture is crucial to reduce CO_2 emissions by 60%-80% by 2050. The EU envisages wide scale deployment of CCS from 2020 onwards. In the Transport sector, improvements in Engine efficiency is required coupled with a move to hybrid & electric vehicles with a market for Biofuels and Hydrogen powered machinery.

References

Janet Wood, Local Energy, Distributed generation of Heat and Power, Institution of Engineering and Technology.