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LOOKING FURTHER AHEAD: A POLICY FOR RENEWABLE ENERGY

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"The UK is poorly prepared, as yet, to face the long-term challenge of reducing emissions from coal, oil and gas to far below present levels . . . . Looking further ahead, a programme for more radical changes will be required."

Royal Commission on Environmental Pollution, 2000

1. INTRODUCTION

1. 1 Definition of Sustainable Energy.

Sustainable development is activity that meets the needs of the present without compromising the needs of the future. Sustainable energy does this in two ways.

- It uses natural ambient energy and is not dependent on a limited supply of fuel. It is effectively inexhaustible or ‘renewable’.
- It does not produce irreversible changes in the environment, especially the atmosphere. It is non-polluting or ‘clean’.

1.2. Exhaustion of Fossil Fuels

In the 1970s the anticipated exhaustion of fossil fuels was the justification for developing renewable energy.

The threat was often exaggerated. At any given time the known reserves of oil were sufficient to meet rising demand for twenty years, but there was no incentive for oil companies to establish new fields beyond the twenty-year horizon. The cynic could therefore respond that there would ***always*** be twenty years of oil left.

Nevertheless, if demand rises exponentially finite reserves will eventually be exhausted. Many of the most easily exploited reserves of oil and gas are now depleted. Each new field to enter production poses greater challenges as development moves to higher latitudes, or further off-shore.

In particular, oil and gas fields in the North Sea are set to decline in output, and future exploration in the UK sector will face the stormy conditions of the North Atlantic. At the very least we should anticipate that in the medium term the real cost of oil and gas will rise substantially.

It must be remembered, however, that the equivalent lifetime of coal reserves can be estimated in centuries rather than decades. If exhaustion of oil and gas were the only threat then we could prepare for a revival in coal.

1.3. Global Warming.

Over the past twenty years global warming has provided a second reason for the replacement of fossil fuels by renewable sources of energy. This has now become the more urgent consideration.

100 years ago Arrhenius predicted that with the use of fossil fuels to drive the industrial revolution there would be a significant increase in the atmospheric concentration of carbon dioxide (CO_2). As CO_2 absorbs infra-red radiation this would cause an increase in the temperature of the Earth. These predictions have proved correct.

Since 1958 accurate measurements of CO_2 have been made from Mauna Loa in Hawaii and these confirm that the concentration is increasing at an increasing rate (0.7 ppmv/yr in the late 1950s; 1.5 ppmv/yr in the late 1990s).

The measurement of the average temperature of the Earth is not easy but records confirm that over the past two hundred years the average temperature of the Earth has risen, and that eight of the hottest years on record occurred during the 1990s.

Increased temperature has several consequences. As temperature increases the sea expands and sea-level rises. This has been confirmed by satellite measurements. Moreover, as sea temperature increases, the flow of energy from sea into atmosphere increases, enhancing cyclonic activity. A consequence of global warming is therefore a growth in the number and ferocity of storms and hurricanes.

1.4 Scientific Confidence

Ten years ago a minority of scientists still denied that CO_2 was responsible for global warming. They pointed to unexplained features in the temperature records: large fluctuations in average temperature from year to year, and a sharp increase in temperature between 1910 and 1940 when CO_2 concentration was not increasing rapidly.

The year-to-year fluctuations were explained by the Pinatubo volcano in 1991. This threw a layer of aerosols into the stratosphere that reflected sunlight back into space. Two cool years followed – the two that were *not* the hottest on record - but after the aerosols had been washed out of the atmosphere the temperature rose again. Subsequently examination of historic records confirmed that volcanoes were responsible for the main fluctuations.

There is still controversy in explaining the temperature rise between 1910 and 1940. There is strong evidence that the magnetic field in interplanetary space increased sharply in strength between 1910 and 1940, and more gradually afterwards. This led to a decrease in the cosmic ray intensity on the Earth. It has been reported that global cloud cover – and hence average temperature – is related to cosmic ray intensity. This preliminary result was seized by some of the fossil-fuel industries as evidence that CO_2 did not cause global warming. This view is not shared by the scientists who reported the increase in magnetic field: they estimate that solar changes may account for 30% at most of the total warming during the twentieth century.

To summarise: there is now an overwhelming consensus among scientists that emissions of CO_2 (plus methane, nitrous oxide and CFCs) are the prime cause of the rapid rise in the average temperature.

1.5 Future Scenario

It is difficult to predict exactly the way temperature will rise if we continue with our present CO_2 production. There are three fundamental problems:

1. As temperature rises, water concentration in the atmosphere also rises. Sometimes water is a greenhouse gas (e.g. as low cloud during nighttime); sometimes it is an anti-greenhouse gas (e.g. as high cloud during daytime). This introduces uncertainty in calculating how much the temperature will continue to rise.
2. The temperature rise will be reduced by negative feedback and enhanced by positive feedback: it is not certain which will be stronger. Negative feedback occurs when the combination of increased CO_2, humidity and temperature will accelerate crop-growth and hence accelerate CO_2 fixation. A major positive feedback would follow the disappearance of ice-cover. Ice reflects sunlight into space and hence cools the Earth. If the ice disappears, the same incident sunlight is absorbed. The disappearance of the northern ice-cap would lead to an extra increase in the temperature at high latitude. This in turn would lead to the release of methane from the Arctic tundra and a second, very dangerous positive feedback would ensue.
3. The time-scale with which oceans respond to atmospheric change is uncertain. It could be 50 years before the full effects of what we have done already will be felt. There ***is*** worse to come, but if we do nothing to cut CO_2 it will be ***much*** worse.

1.6 Global Imperative

There are two reactions to the link between the burning of fossil fuels and global warming: adaptation or mitigation. The first assumes global warming will continue and the answer is to prepare in advance for climate change with stronger buildings, stricter planning guidelines and higher flood defences.

Adaptation seems prudent, but unless accompanied by strenuous attempts to mitigate the degree of warming it is dangerous and misleading. If positive feedback kicks in seriously no amount of adaptation will be enough. The only prudent policy gives determined priority to halting the temperature increase. Global warming is the most important political question on the agenda of every legislature in the world.

Faced with this the Kyoto Conference agreed on a 7% reduction in CO_2 emission. Yet scientific climate models show that a 7% reduction has virtually no effect on the long-term scenario. A reduction of at least 50% is needed to make a significant difference, and 50% reduction overall implies a much greater reduction by the more prosperous countries to allow industrial expansion in the poorest countries.

The main achievement of the Kyoto Conference was not the aim of a 7% reduction: it was the establishment of an international framework for controlling greenhouse emissions and even this has still to be ratified. However, once the governments of the world are finally convinced of the danger we can anticipate 7% becoming 50%.

1. REDUCTION OF CO_2 EMISSION FROM ELECTRICITY GENERATION

2.1 Meeting Present Targets

The present UK government has set a target of a 20% reduction from the 1990 level of CO_2 emission by 2010. This seems a commendable target that is more ambitious than the Kyoto requirement (12.5%) and more ambitious than most other European countries.

However, this is misleading as a dominant feature in UK policy is the replacement of coal by gas.

Natural gas is a hydrocarbon, and burning gas generates both CO_2 and water, so that the CO_2 emission for a given heat output is less than for coal. It seems self-evident that a cut in CO_2 emission by substituting gas for coal is a wise move. Not necessarily so . . .

When gas is burned directly for space heating the overall thermal efficiency is about 80%. If the same gas is used to generate electricity in a gas-fired station, and the electricity provides space heating, the overall efficiency is about 40%. This can be increased to 70% if the generation of electricity is part of a Combined Heat-and-Power (CHP) scheme.

It follows that if gas is used to generate electricity without CHP it produces about twice the CO_2 per unit of space heating that it would if burned directly. This is the reason why, for many years, it was forbidden to use gas to generate electricity.

So does a gas power station reduce or increase greenhouse gas? . . . It depends on the situation at the time when gas is finally exhausted. If at that time all electricity is generated by renewable technologies it will appear to be a wise move to use gas rather than coal during the transitional period. If however coal is still being used to generate electricity when the gas reserves are exhausted, then the use of gas to generate electricity will have actually made global warming worse than it might have been.

There is an irony in this. Unless present practice is changed, the very policy that helps the UK exceed Kyoto requirements may actually increase CO_2 emission! Whatever short-term advantages are offered by gas, it a ‘dirty’ technology, even if not as dirty as coal.

2.2 Meeting Stricter Targets (Nuclear)

A genuine way to achieve targets stricter than the Kyoto requirement is to substitute nuclear energy for fossil-fuels. There is no denying that during normal operations nuclear power stations produce virtually no CO_2. It is also argued that nuclear power is a mature technology that provides a very intense source of energy so that a single site provides sufficient electricity for the whole of Wales.

The arguments against nuclear power are well rehearsed. The worst possibility is a catastrophic accident, but there are also the endemic, unsolved problems of waste disposal, metal fatigue caused by radiation, and decommissioning. If these three factors are taken into account they lead to a fourth disadvantage – cost. The true cost of nuclear power makes it a very expensive technology.

There remains the dream of a fusion reactor, producing power from the fusion of hydrogen nuclei to produce helium. What generic problems would haunt fusion power can only be imagined as no successful fusion generator has yet been designed. In the 1950s it was thought that fusion power was fifteen years away. Over forty years later, despite enormous research expenditure, optimists claim it is fifty years away.

To summarise: if the only choice were between continued use of fossil-fuel or a switch to nuclear power it would be necessary to go nuclear. However that would be an unattractive scenario. Hence the strategic importance of clean, renewable energy.

2.3 Meeting Stricter Targets (Non-Nuclear)

To reduce CO_2 emission to meet the strictest targets the first step is to reduce consumption. This is NOT an alternative to renewable generation technology, but it IS the first priority. At the moment we have a wasteful pattern of electricity use, and Wales consumes a total of about 16 TWh (or 16 billion kilowatt-hours) pa from the grid.

- Electricity is used for space heating and for air-conditioning but the insulation and reflectivity of buildings in Wales are still, in general, far below the standards set in many European countries. According to the Energy Saving Trust only 7% of UK homes are classified as "good" in energy efficiency terms. Schemes such as the Home Energy Efficiency Scheme are a start but we need to do much more. We must overcome a prevailing attitude that refuses to support adequate grants for improved insulation in ***all*** buildings on the grounds that some people or organisations have already paid privately to achieve the same levels of insulation. We all gain from reduced power consumption, and improved targets for insulation standards in all existing buildings - new or old -

should be introduced as a priority. In the Welsh School of Architecture we have valuable expertise in this field and this must be used effectively.

- Solar heating, either in the form of solar panels or in the basic design of the building, is now a reliable technique that should be a standard feature of all new buildings, especially public buildings.
- Until recently energy efficiency was one of the least important factors in the design of ‘white goods’. Designers of freezers and refrigerators paid attention to cheapness, slim-line appearance and maximum internal capacity. The best refrigerators and freezers have a power consumption about quarter of the worst examples. More stringent standards should be imposed throughout Europe.
- TV sets and computer monitors are major - and expanding - consumers of electricity. The introduction of digital technology and higher resolutions adds to the problem. Low-energy monitors will dramatically cut power consumption of and this could be a technology to encourage in Wales.

A reduction of total electricity consumption by 33%, while meeting all our present demands, is a target that could be met without any new technology and without imposing any discomfort or lack of facility for the population.

At the same time we may wish to increase electricity consumption in certain sectors, such as an integrated public transport programme where mainline trains, light railways and trams are electrically powered.

We should therefore aim to cut overall electricity consumption by 25%, and this would mean a total annual consumption in Wales of 12 TWh. Let us assume that at present about 4 TWh pa is nuclear generated and 12 TWh pa generated from fossil fuels (notional figures). By reducing total consumption by 25%. and introducing 4 TWh pa of renewable energy in place of fossil-fuel generation, we will reduce the level of CO_2 emission from electricity generation by a factor between two and three depending on how much nuclear capacity remains.

Our target by 2010 should be to generate 4 TWh by renewable, non-polluting methods. After 2010 it is likely that most nuclear power stations will be decommissioned and therefore by 2020 it will be necessary to build new nuclear power stations or else expand renewable energy still further. The renewable technologies necessary to fill this gap are still developing so it is impossible to set separate targets for each in turn. However, as part of a full strategy it is possible to outline the programme of research and development that must start now if these technologies are to be available in the future.

The technologies of using wind power, hydro-electricity, biomass, tides, waves and sea-currents, solar heating and photo-voltaics are all, to some extent, familiar. Let us consider how they might be combined to meet the target, concentrating on technologies where Wales has some special geographical advantage or has already acquired sufficient expertise to make a significant contribution.

1. **CLEAN RENEWABLE ENERGY (2000-2009)**

To produce 4 TWh pa of electricity from clean, renewable sources by 2010 it will be necessary to rely on technologies that are already mature and competitive. This limits the effective choice to wind power, hydro-electricity or biomass. Tidal power may also contribute towards the end of the period, but major tidal generators have a long lead time and are more likely to contribute to the programme for 2010 to 2019.

3.1 Wind Power

Wind power is a proven and mature technology, operating near to the maximum theoretical efficiency, and economically competitive.

There is one major drawback with wind power. The output of a turbine is proportional to the volume of air passing through the sweep of the turbine blades, which is proportional to the speed of the wind. The output is also proportional to the kinetic energy of the wind per unit volume, which is proportional to the square of the wind speed. The output power therefore varies as the cube of the wind speed, so that as wind speed varies by a factor of 2 the output varies by a factor of 8.

As a result wind turbines operate efficiently within a narrow band of wind-speed: if the speed is too low the power output is negligible; if the speed is too high the rotation speed of the turbines reaches the safety limit. The output power from any location is therefore sporadic with an average power output only ~28% of the rated maximum.

At an ideal location there would be a steady wind of about 6 ms^{-1}. Wales is suitable for wind power because our extensive uplands are swept by relatively steady winds for most of the year.

However, while a wind turbine might produce a significant amount of electricity over the whole year there are periods with no power output at all. As a consequence wind power is best supported by an adequate storage capability (e.g. pumped storage) or access to an alternative source of power that can be introduced very quickly and at any time (e.g. a gas turbine). For this reason in any ideal energy strategy wind power should be limited to about 15% of the total power output.

The practical consequences of this for Wales depend on whether we are considering power output in Wales alone or in the UK.

With the target of using wind power to produce15% of the present electricity consumption in Wales, we will need an annual output of about 2.4 TWh. If the average power of a turbine is 28% of the rated maximum, then 2000 wind turbines with a rated output of 500 kW (or the equivalent) are needed, whether on- or off-shore.

If care is taken to derive a strategic spatial plan where the turbines are distributed in remote sites throughout Wales (e.g. on Epynt or the moorland behind Tregaron) it should be possible to achieve our target in a way acceptable to the vast majority of people..

One piece of infrastructure is needed to make this a practical possibility – a transmission line to carry power from a remote site to the grid. It was an unfortunate feature of early wind farms in Wales that in order to take immediate advantage of the initial high subsidy from the Non-Fossil-Fuel Obligation sites were chosen close to existing electricity sub-stations – and this meant close to existing settlements. However, with a coherent spatial plan it will be straightforward to provide a grid connection to a chain of sites where the turbines would be more remote from any settlement.

Wind turbines have excited disproportionate hostility from a small minority. Some of the early projects did cause an unexpected level of noise, but this problem has been largely overcome. It is true that to be effective wind turbines must be on exposed ground and as high as possible, so they are highly visible. This is now the only serious objection to the series of proposed wind-farms, and this objection has been strengthened by the influence of the Countryside Council for Wales that has embarked on an exercise to give a numerical evaluation of landscape quality and inter-visibility.

These objections, pursued through the planning procedures of local authorities and the National Assembly, have caused serious delays in the introduction of wind power. In the past few months two proposals for wind-farms, approved by the County Council, have been called in by the National Assembly. This has created a widespread feeling that the National Assembly is opposed to all such proposals. There is evidence that inward investment in the wind industry has been affected by this reputation. Vesta, for example, has a policy of investing in manufacturing capability in any region where there is a prospect of 60 MW or more new installed capacity pa. Recent decisions make such investment less likely.

Off-shore wind power arouses less controversy but it is questionable whether this immunity from opposition will survive the construction of the first major off-shore wind-farm. An off-shore wind farm would be seen regularly by far more people than many of the existing hilltop turbines. Off-shore wind-turbines would undoubtedly be more expensive to construct and service than their on-shore counterparts, but this disadvantage would be partly offset in the short-term by the prospect of special government support and in the long term by the more consistent wind speeds experienced at sea.

It is therefore a high priority for the Assembly

- to accept a target figure for overall power output from wind energy
- to agree on a spatial strategy for locating wind-farms, and
- to establish firm guidelines for planning purposes, with a presumption in favour of wind farms on suitable sites.

3.2 Hydroelectricity

World-wide hydroelectricity is the most important form of renewable energy and it might seem that hydroelectricity could make a major contribution to the electricity needs of Wales. A plant like the Cwm Rheidol power station is extremely efficient and produces peak-time electricity rapidly, on demand, at a very competitive price.

To put this in perspective, however, it must be remembered that Cwm Rheidol occupies the most suitable site for hydroelectricity in the whole of Wales, it involves a very extensive catchment area, and yet it only produces 0.1 TWh pa - sufficient to meet the electricity demands of Aberystwyth. It would require 24 hydroelectric schemes similar to the Cwm Rheidol station to match the power output of the wind turbines described above – and 24 sites of this kind do not exist. The truth is that Wales is too small, our mountains are not high enough and our rainfall is not enough to allow hydroelectricity to make a contribution similar to that enjoyed by countries such as Norway or Sweden.

Nevertheless, hydroelectricity is economically competitive and through the development of a large number of small-scale schemes, including river-flow generators, hydroelectricity could provide about 0.4 TWh pa. For example the Dyfi Eco Valley Project includes a number of small hydroelectric schemes. These initially met objections from the Environment Agency but these problems have been resolved.

It should be added that hydroelectricity in the form of pump-storage stations like Dinorwic and Ffestiniog could play an important part in storing energy generated by sporadic, renewable sources such as wind-power. Pump-storage was designed to match a constant generating source (such as a nuclear power station) with a fluctuating demand (such as the surge that follows TV coverage of a major sporting event). However, the technology is just as relevant for matching a fluctuating generating source, such as a wind-farm or a tidal generator, with the base-load demand. This has been recognised by the NAfW in setting a Business Rate that classifies pump-storage as an environmentally-friendly technology.

3.3 Biomass

The next significant contribution to the renewable generation of electricity is likely to come from ‘biomass’ – the burning of recently-grown wood in small-scale units which combine electricity generation with the provision of low-grade heat for industrial or domestic use (Combined Heat and Power or CHP). To this must be added the use of waste wood to provide fuel pellets that can be used instead of coal or oil in stoves and central-heating systems.

It might seem that burning wood produces as much CO_2 per TWh as burning coal or oil. However, the crucial difference is that biomass is not a fossil fuel, laid down over many millions of years, but a ‘short-rotation’ fuel where CO_2 is first taken from the atmosphere and a few years later most of it is returned. If this is achieved by planting new trees, such as willow, on previously bare upland sites, the net effect is to reduce the level of CO_2 in the atmosphere. This technology has the advantage of providing a regular source of income for farmers owning marginal land in upland areas.

If forestry waste is used instead of 'short-rotation' fuel it could be argued that this releases CO_2 taken from the atmosphere decades ago, and so should not be regarded as a genuine reduction in net CO_2 emission. However, if forestry waste is left to rot it generates methane that as a greenhouse gas is far more powerful than CO_2. (This is also the reason why using landfill methane to generate electricity is important) .

The main drawback of biomass is that it requires a considerable amount of forest waste or wood from short-term coppices to support each power station, and at present diesel lorries are the proposed method of transport. It is a simple mathematical law that the transport involved in tonne-kilometres per hour for each MW of generating capacity varies as that capacity to the power 3/2. If we increase the generating capacity by 4 the transport increases by a factor of 8. For the scale of plant proposed in Wales this is not a serious factor in the energy equation but it is a serious factor in winning public acceptance. This factor would limit the maximum capacity of a biomass generator to about 20 MW. This limit is also appropriate to ensure the optimum use of the waste heat provided in thermal generation of electricity (CHP).

Before any contracts for short-term coppicing are agreed, the source of fuel would be forestry waste, and this imposes a limit on the total capacity that could be commissioned initially. Forestry Enterprise are unable to guarantee supplies of forestry waste for all the biomass generators that have been proposed, and the delay in reaching a decision on the Newbridge-on-Wye proposal is frustrating any progress on this until the outcome of the planning appeal is known.

In order to expand the capacity beyond this limit it would be necessary to encourage short-term coppicing of suitable wood, such as willow. This would require a lead-time of at least three-years, followed by a guaranteed contract for the farmers involved. To ensure that this happens will require initial funding but in some areas support will be available from European structural funds.

If we assume that by 2010 the supply of forestry waste and short-term willow coppicing could support 4 biomass generators of 20 MW capacity then the total output would be 0.7 TWh pa. In addition, at each site there would be an even greater quantity of low-grade heat, suitable for space-heating, timber processing, horticulture, swimming pools etc. (In planning the development of biomass it must be remembered that the efficient use of the waste heat is an important factor in making the whole process economically competitive).

Alternatively waste wood can be used to produce fuel pellets as an alternative to the use of fossil fuels. A pilot scheme has been started, using waste timber from the furniture industry. The main difficulty in this case is to establish a market for the fuel before regular production has begun (or, alternatively, to establish regular production before a market is guaranteed). This may also require initial funding.

1. **CLEAN RENEWABLE ENERGY (2010-2019)**

There are several other renewable, non-polluting generating methods that will surely be relevant in Wales but which are not yet commercially competitive, or are still in the development stage. These include tidal generation, wave machines, sea-current turbines, and photo-voltaics. It is impossible to quantify exactly what contribution each might make to our total electricity demand by 2020. By that date most existing nuclear stations will have been decommissioned and unless a new generation of nuclear station is built it will be from among the following list of renewables that the technologies necessary to fill the energy gap will be chosen.

4.1 Sea Power

Generation of electricity by tidal flows through an estuarine barrage has been demonstrated successfully at La Rance in France. This confirms that over the long term this is a mature, dependable and cheap technology. It is a technique where Wales enjoys a very significant advantage, with the tidal reach in the Severn estuary the second highest in the world. Tides are entirely predictable and a single station provides power about four times a day. If several schemes were deployed along the coast of Wales, the 5-hour range in the time of high tide at different parts of the coast would ensure an almost constant supply to meet base demand.

Many schemes have been proposed over the years for Wales, ranging from relatively small projects, such as a 60 MW tidal generator in the Conwy estuary, to the 8.6 GW Severn barrage, which could generate more than the total electricity demand of Wales.

The main problem facing an estuarine barrage is the environmental impact, an impact that is much more significant than that of a wind farm, affecting far more people directly. This is especially true of the proposed Severn Barrage whose consequences would be so far-reaching that it would be unwise to make a full commitment to such a massive project without considerable experience with smaller projects.

Recently Tidal Electric have proposed a tidal generator where an oval off-shore dam is used instead of an estuarine barrage. It might seem that an off-shore system must be far more expensive but an estuarine reservoir has a bottom that slopes sideways and inland so that the volume of impounded water is far less than for an off-shore system of similar area but constant depth.

The key parameter in assessing the cost-effectiveness of such an off-shore project is:

(area of water impounded x tidal range) / volume of dam.

The numerator is proportional to the square of the radius of the enclosed area and the denominator proportional to the radius itself. It follows that the larger the project the more economical it will be.

Two alternative schemes have been proposed for a site close to Rhyl where they would combine the generation of electricity with protection of the coast from storm-driven flooding. In the smaller scheme a dam wall 15 km long would impound an area of 9.6 sq.km. and produce 0.5 TWh pa. In the larger scheme a wall 37 km long would impound an area 52 sq.km. and generate 2.8 TWh.pa.

Such a scheme would have a large visual impact but if properly landscaped it would appear from land as a natural island. It would have the advantage over estuarine barrages of having a negligible effect on existing commercial and leisure interests.

Although this must be regarded as a proposal for the future, it is a proper subject for a full design study and this should be supported to provide a reliable costing.

Similarly wave-power machines and sea-current generation are likely to make a significant contribution to electricity generation in Wales within the next 20 years.

These cannot yet be regarded as mature technologies. Considerable work has been carried out on different forms of wave machine, which fall into three general categories, but so far most of the prototypes have failed mechanically - primarily due to damage caused during very stormy conditions. Moreover, some of the proposed wave machines are very large structures that would have a considerable visual impact.

However, the first commercial wave-machine has now been commissioned by WaveGen on the island of Islay in Scotland. Although this is a relatively small generator it may lead to successful commercial investment along the Atlantic coast of Wales.

Sea-current turbines are an even newer technology that holds great promise for Wales. At several points along the Welsh coast there are very strong tidal currents and these provide a large potential source of power e.g. in Menai Straight, Bardsey Sound, Wylfa Head. In many ways this is a technology similar to wind power but because of the much greater power density of water when compared with air the diameter of turbine rotation necessary for a rating of 1 MW power is 20m instead of 60m. Such a turbine has the advantage of being almost invisible. It is obvious, however, that great care must be taken to ensure that it is not a hazard to shipping and it is not certain how damaging such a turbine would be to fish and sea mammals.

There is no doubt that Wales's position facing the Atlantic means that at some time in the future all these techniques will be used to help meet our energy requirements. They may not join the first generation of renewable energy projects but nevertheless it is not too soon to start planning the research and development necessary before such projects reach fruition. This should involve a partnership of our engineering companies and community enterprises, our universities and the Assembly itself. A full survey of wave activity and current flow around the coast would be a suitable first step.

4.2 Solar Electricity

Finally we have photo-voltaics. Up until the present time the cost of PV electricity has been prohibitive, although the largest PV array in operation in the UK is on the roof of the Ford factory. We are now at the stage where it is confidently claimed that if a sufficiently large market for PVs were guaranteed large-scale production could make the cost competitive. Very large investment into PV is being made in countries like Japan and it is very likely that in the near future PV generation should be added to the range of renewable technologies. This could be a target sector for inward investment.

5. CONCLUSIONS

5.1 Political and Economic Significance of Renewable Energy

The prime motivation for the development of renewable energy is the global imperative of mitigating the threat of climate change. The fatalists will argue that it is folly to think that Wales can make any difference. They will add that unless the whole world – and especially the USA – share the perception of threat then the actions of a small country will be of no avail.

The moral answer is clear: we should do it because it is the right thing to do.

The political answer refuses to dismiss the possibility of a small country taking a lead on a major issue – as Ireland did on the Nuclear Non-Proliferation Treaty and the Nuclear Test-Ban Treaty.

The third answer is economic, and this is totally convincing.

There are some obvious economic advantages in renewable energy. Both wind-power and biomass will bring extra income to rural areas where the need for diversification is acute.

In the longer term Wales will benefit from a reliable supply of electricity from renewable sources at a competitive price in a world regime that will increasingly penalise polluting technology.

However, the greatest advantages may lie in the contribution renewable energy can make to our overall economic strategy. In applying sector selectivity to economic development it is necessary to identify sectors that are certain to grow over the next twenty years, and of these choose the sectors where Wales has some intrinsic advantage.

Every crisis creates an opportunity. If the scientific analysis is correct (which it is), and if events reinforce that analysis (which is happening), then sooner or later the whole world will recognise the threat. When that happens, the reaction will be swift and substantial. It follows that renewable energy is an industrial sector certain to continue its rapid expansion over the next twenty years. The existing fossil-fuel industries will be partly replaced by a new spectrum of industries covering the whole range of clean, renewable energies. In Denmark, for example, the renewable sector already employs 15,000 people at home and a further 15,000 abroad and these numbers are increasing rapidly.

In this sector Wales has the intrinsic advantage that geographically we are an ideal location for the development of several of the key technologies, especially wind, tide and sea current. We also have the heritage of heavy manufacturing and civil engineering that are key ingredients for success.

The most promising way in which a strategy of encouraging renewable energy could bring large economic dividends is via exports to a rapidly-growing world market. The important guidelines in developing an export industry is to find niche markets where we are not in direct competition with one of the established giants, such as Denmark or Japan. Thus Cambrian Engineering have established a large export business in manufacturing the towers for wind-turbines with 70% of their output being exported. Dulas Engineering have established an enviable reputation for designing a wide range of successful hydro- and solar-devices, including a solar-powered refrigerator adopted by the WHO for storing medicines in remote tropical regions.

This is therefore a sector that must have a prominent position in our revised NEDS.

5.2 The Role of the National Assembly

In promoting renewable energy there are several crucial steps that will be the responsibility of the National Assembly.

- **Targets**. The NAfW can set the targets. This paper proposes an ambitious target – the aim of generating 4 TWh of electricity through renewable, non-polluting methods by the year 2010 - but in the context of Wales this is a realistic target. In meeting this target the mature technologies of wind-power, hydroelectricity and biomass could provide 3.5 TWh as indicated above. If we assume that at least one of the next-generation technologies will become commercially competitive in the near future there should be no difficulty in providing the extra 0.5 TWh.
- **Spatial Strategy**. The NAfW can develop a comprehensive spatial strategy for the growth of the renewable sector. Renewable energy is a low-intensity resource and the exploitation requires a large number of sites. So far the selection of sites has been ad hoc, without any overall plan. Thus the locations of on-shore wind farms and biomass power stations have already caused controversy. Without careful planning the locations of off-shore wind turbines, tidal generators, wave machines etc could prove even more difficult. The whole area of Wales and the whole coastline must be assessed to identify the most suitable candidate sites for each technology and to distribute the final selection of sites to avoid excessive concentration. The spatial strategy will also include the most efficient network of power lines to provide grid connection for remote facilities (e.g. wind farms in the more remote part of the Cambrian Mountains).
- **Temporal Strategy**. Many of the projects listed in this paper, especially the candidates for development after 2010, require a substantial programme of research and development, followed by a long lead time for construction and commissioning. It is essential that this work should begin well in advance of the time when the facility is required. During the next ten years when we proceed with the careful development of wind-power, hydro-electricity, biomass and solar heating we need to start the preliminary work for the next generation of technologies such as tidal power and sea-current generators. This will involve a partnership of the electricity companies, engineering companies and community enterprises, universities, local authorities and the

National Assembly itself.

- **Planning Guidelines**. The NAfW must establish planning guidelines to ensure a presumption in favour of projects that conform with the overall strategy. At the same time the guidelines followed by the Countryside Council for Wales must be reviewed. Over the past year a number of excellent schemes that would be essential ingredients of any plan for renewable energy – including two wind farms and a biomass power station - have been seriously delayed by planning objections either at local or national level. As a result post-devolution Wales is gaining a reputation for hostility to renewable energy and there is already evidence that this is proving a deterrent to investment in the renewable sector.
- **Business Rates**. The decision to recognise the pump-storage systems in Dinorwic and Ffestiniog as key elements in a renewable energy strategy, and hence to make a substantial reduction in the business rate, was hailed by the ecumenical organisation Cytun as the most important decision made by the National Assembly in its first year. At the next review of Business Rates this decision must be consolidated in a formula that will give appropriate support to the whole scctor.
- **Influence on Legislation**. Some aspect of policy that would encourage renewable energy lie outside the control of the NAfW but the opinion of the National Assembly should be expressed strongly when the corresponding legislation is proceeding through Westminster. For example, it could be argued that the proceeds of the Climate Change Levy should be used to support innovative projects in renewable energy rather than distributed as a reduction in National Insurance. Similarly the premium rate for renewable energy in the new Utilities Bill, based on the assessed cost of biomass power, is thought by some commentators to be too low: the view of the NAfW should be expressed.

In conclusion, we have a fantastic opportunity to use the powers of this Assembly to promote work of global significance and at the same time to install a firm pillar in our strategy for economic development. It is vital that we seize this opportunity.