THE DTI SOLAR ENERGY PROGRAMME AND THE ROLE OF SOLAR PV IN BUILDINGS

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This paper describes the current government activities relating to Photovoltaics in buildings as implemented in the DTI New and Renewable Energy Programme. To set the context the paper starts with a brief review of the overall prospects for renewable energy in global, European and UK contexts. This is based on work previously undertaken for the DTI[1]. For comparison, the current state of deployment of renewable energy in the UK is reviewed. This then leads into a brief description of the UK government's programme on new and renewable energy. Activities in the programme relating to the application of building-integrated photovoltaics (BIPV) are then described.

PROSPECTS FOR RENEWABLE ENERGY

Renewable energy is the term used to describe a wide range of naturally occurring, replenishable energy sources. It is estimated that at present somewhere between 15 and 20% of current global energy needs are met from such renewable energy sources. This contribution is predominantly from traditional biomass, hydro electricity, wood and geothermal sources.

It is widely accepted that renewables have the potential to meet an increasing proportion of global energy needs over the coming decades. The technologies which will contribute to this growth are at widely differing stages of development. Some, such as traditional hydro electricity are well established, whilst others such as wind, are being deployed commercially but are not yet fully competitive. Energy crops are at the demonstration stage, and require further support before widespread demonstration and deployment is possible. Photovoltaic technology is finding commercial application in niche markets, but before mass markets (particularly in the developing world) can be opened up there needs to be substantial support for product and market development which together could lead to significant cost reductions.

Future Global Prospects

There have been a variety of studies of how the potential global market for renewable energy may develop. These have been carried out by a range of organisations, for example; the International Energy Agency, the World Energy Council, the United Nations, and Shell International. These studies all involve scenario based modelling, and in general consider two types of scenario - those driven by economic growth ("business as usual") and those driven by environmental concerns.

Taken as a group the studies contain the following broad messages:

- A significant expansion of renewables in all scenarios, for all the studies (see Table 1). This is a reflection of the ability of renewables to make positive contributions against a number of underlying scenario drivers.
- Different renewable technologies are important in different regions depending on the resource availability and the market demands.
- In the near to medium term growth in renewable energy market penetration is rather modest for the majority of scenarios. In the long term growth rates increase as performance improvements acquired in initial niche markets translate into a vigorous penetration of broader markets.
- Renewables tend to make increased contributions as a result of gradual improvements in design and efficiency; i.e. they no longer need to make radical breakthroughs.
- Biomass is the dominant renewable fuelstock in the long term for most of the scenarios.

- Renewable fuels could make significant contributions in transport markets if both the yield of useable energy per hectare and vehicle efficiency can be greatly improved.
- Scenarios with environmental drivers and/or high economic growth tend to be more bullish with respect to the deployment of renewables.
- Renewables market penetration can be significantly enhanced by the liberalisation of energy markets. This effect is particularly prevalent post 2020 when energy markets become ever more diversified and flexible.

Table 1: Summary of Modelling Studies

Study	Date	Renewables contribution
IEA	2010	4% of electricity, 2% of total energy (excluding 'non commercial use', estimated at 15-20% of total energy)
WEC	2050	Up to a 25% increase in global markets (rising from a current level of approximately 18%)
UN	2050	Current contribution of 20% will rise to 60% of electricity and 40% other fuels
Shell International	2060	Up to 40% of total energy supply

In most of these studies the total contribution made by renewables energy is aggregated. However, it is possible to draw out those technologies which will make the most significant contribution in three time frames:

- **Short term** (i.e. available now): small hydro (typically less than 10MW), energy from waste (from waste combustion or via landfill gas collection), onshore and offshore wind power, active and passive solar, stand alone PV (particularly in niche markets), biomass residues, and high enthalpy geothermal.
- **Medium term** (i.e. should be commercial over the next 10 to 15 years): larger scale PV, energy crops, fuel cells, and geothermal aquifers.
- **Long term** (i.e. may be commercial within 25 years): onshore and offshore wave, photoconversion, solar thermal electricity.

The Developing European Union Market

Renewable energy sources are likely to make a major contribution to European energy markets. At present they fulfil just 6% of primary energy requirements in the EU but a European Commission White Paper and Action Plan[2] published in late 1997 proposes the ambitious target of doubling this to 12% by 2010, thereby saving over 400 million tonnes a year of CO_2 emissions. Current contributions come mainly from large-scale hydro and traditional use of wood, both of which have limited growth potential. Hence the required additional contribution is expected to come from the "newer" technologies such as wind power, modern use of biomass and waste, landfill gas and solar energy.

Achieving this target represents a major challenge for the Commission and Member State governments and European industry which will have to deliver the additional capacity. The White Paper estimates the total investment to achieve the target at some 165 billion ECU, creating over 500,000 additional jobs in the EU. The business in 2010 is valued at 37 billion ECU, with a further 17 billion ECU from exports in the expanding world markets. This will clearly represent a major opportunity for UK and European industry, which already leads the world in several renewables sectors.

Prospects in the UK

The future prospects for particular renewable technologies in the UK will be determined by the commercial availability of that technology, the presence of an exploitable resource, the economic competitiveness of the technology compared to other available options, and the overall demand for energy. Analyses to explore future prospects are therefore complex, and results highly uncertain. Recent studies[1] of future market prospects have been carried out by using a computer model, which has access to a suite of future energy price and demand scenarios. The model, and basic approach is the same as described in Energy Paper 62[3].

The model is configured for the large-scale, national, energy markets. Niche markets have not, typically, been modelled. It also uses the same future fuel price and energy demand scenarios as used by DTI in its own energy projections (published in 1995 as Energy Paper 65[4]), and the Central-Low and Central-High (i.e. central growth rate with low and high fuel prices) "business as usual scenarios" from that report have been used to assess the future prospects of renewable energy technologies.

In summary the modelling runs show that:

- The cost effective level of renewables generation in 2010 lies in the range 16.0 TWh to 41.2 TWh, which represents between 4.2 % and 11.0 % of total electricity generation. By 2025 this increases to between 26.0 TWh and 155.4 TWh which is 5.7 % to 33.9 % of total electricity generation.
- Renewables also have an important, and cost effective, role in helping to reduce emissions of CO_2. Future CO_2 saving may be up to 13 million tonnes (10% of total ESI emissions) when compared to cases where no new renewables are deployed.
- The results are largely robust. However, the uptake of some technologies, such as, onshore wind and wave, are sensitive to assumptions regarding their future cost and performance characteristics. If the costs assumed in the current data are not achieved then significant deployment of these technologies may be delayed.

The results show that by 2010 onshore wind, waste incineration, and exploitation of landfill gas make contributions greater than 2 TWh/y in all scenarios along with new small hydro and combustion of poultry litter which make smaller contributions. In some scenarios offshore wind and energy crops can also make contributions above 2 TWh/y, and tidal stream offers a small contribution under certain scenarios. By 2025 energy crops, offshore wind and wave options also make a significant contribution in all scenarios and biomass residue based technologies (forestry residues and animal slurries) and PV (integrated within buildings) may also contribute in some circumstances.

The model calculates future potential contributions from the range of technologies on a rather narrow economic basis and rigidly selects technologies on cost alone. The model cannot readily include flexible assumptions regarding factors such as social attitudes to technology (e.g. as expressed through the planning system), or realistic market penetration curves. A sensitivity analysis was undertaken to try and address these issues.

Overall, the sensitivity analysis indicates that there are different ways in which high levels of renewable penetration into the UK electricity system could be achieved, using different technology mixes. This is reassuring, but in all cases there are a number of significant technical, commercial and non-technical barriers that will need to be faced if actual deployment is to be achieved.

CURRENT POSITION OF RENEWABLES IN THE UK

In the UK, renewable energy currently produces about 2% of UK energy demand equivalent to 2.3 million barrels of oil. Use of renewable energy in the UK has more than doubled since 1990[5]. The main market stimulation mechanism for renewable energy in the UK has been the Non Fossil Fuel Obligation (NFFO). This was introduced with the aim of facilitating the deployment of technologies which are close to being able to compete commercially in the liberalised UK market and are able to make a significant contribution to electricity supplies in the short term. Under NFFO the electricity supply companies are obliged to establish a certain capacity from renewable energy projects, with premium prices payable to the generators for each unit of electricity produced for a set period of time. Periodically orders are set which increase the capacity required from Renewables. Each order is broken down into specific technology bands, and contracts are awarded to the most price competitive schemes within each band. An important underlying principle has been that the price premium payable should reduce with each successive order.

To date there have now been five NFFO orders, the most recent being concluded in September 1998. Three rounds of the Scottish Renewables Order (SRO) and two Northern Ireland NFFO Orders have been completed. Details of how this breaks down as a function of technology is presented in Table 2.

It is generally agreed that NFFO is effective in stimulating the commissioning, and efficient operation, of new capacity and hence delivering associated environmental benefits. NFFO has also achieved the aim of reducing prices in successive orders (eg wind energy prices reducing from 11 p/kWh to 3.1 p/kWh and landfill gas prices

reducing from 5.7 p/kWh to 2.9 p/kWh over five successive orders). There are many factors which underlie these reductions including some administrative factors such as the length of contract over which the capital cost of the system must be recovered. But there has also been a real reduction in costs, with reductions in the capital and operating costs associated with the projects. In particular the costs of financing projects which have appeared in successive rounds has reduced, as the financial community has become more familiar with the technologies and understand the associated risks better.

Table 2: NFFO Contracts and Capacity (as at 31 December 1998)

Technology	Contracted		Commissioned	
	Number	Capacity (MW DNC)	Number	Capacity (MW DNC)
Biomass/Energy Crops	31	243	6	64.3
Hydro	141	92	51	35.1
Landfill Gas	315	673	109	207.6
Municipal and Industrial Waste	88	1376	13	180.0
Sewage Gas	31	34	24	25.0
Wind	274	1076	58	137.7
Totals	**880**	**3494**	**248**	**649.7**

DTI SOLAR PROGRAMME ACTIVITIES

The DTI has provided support for both Passive Solar Design (PSD) and Active Solar Water Heating since the 1970s and both technologies are now understood and established. PSD is now considered as part of the holistic low-energy design of buildings. The messages from the PSD programme have been fully integrated with the DETR Best Practice Programme for energy efficiency in buildings.

PV Programme Development

In 1990, a review[6] of PV power technology commissioned by the then Department of Energy and undertaken by ETSU suggested that PV systems integrated into the fabric of new UK buildings could in the future provide an environmentally benign power source at a cost competitive with conventional sources. This conclusion was based on certain assumptions considered to be reasonable at the time:

- the integration of the PV system into the building fabric, thereby avoiding a proportion of the capital cost;
- the use of the power generated within the building;
- a reduction in unit costs, associated with a growing PV product market and higher levels of production.

Subsequent to this review of the technology, a small scale PV Programme was initiated by the DTI, implemented by ETSU, as part of the New and Renewable Energy Programme. In March 1994 Energy Paper Number 62 (EP 62)[3] was published setting out the Government's policy:

'Government Policy is to stimulate the development of new and renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable in order to contribute to:

- diverse, secure and sustainable energy supplies;
- reduction in the emission of pollutants;
- encouragement of internationally competitive industries.

'In doing this it will take account of those factors which influence business competitiveness and work towards 1,500MW (Declared Net Capacity) of new electricity generating capacity from renewable sources for the UK by the year 2000.'

As a result of this policy review the PV programme currently has the following main aims:

1. To assess photovoltaics maintaining the option of developing and deploying at a later stage.
2. To encourage internationally competitive industries to develop and utilise capabilities for the domestic and export markets, taking account of what influences business competitiveness.
3. To quantify environmental improvements and disbenefits associated with photovoltaics.

Recognising the large number of players with interests in PV, these programme aims are being pursued collaboratively with a number of other organisations including the Engineering and Physical Sciences Research Council, the UK industry, the programmes of the European Commission and relevant programmes of the International Energy Agency.

In 1997 the new Government announced its proposals for renewable energy: 'The Government propose to undertake a new and strong drive to develop renewable energy sources in line with our manifesto commitment. To this end I anticipate reviewing policy including considerations of what would be necessary and practicable to achieve 10 per cent of UK's electricity needs from renewables by 2010 and how renewables can make an effective contribution to meeting requirements for greenhouse gas reduction commitments. I will make an announcement in due course. In the meantime, the Government's new and renewable energy programme, currently underway will continue.' As part of this review process a consultation paper[7] was published in April 1999. This consultation is expected to result in new programmes for renewable energy.

Industry Consultation

As noted earlier, building-integrated PV (BIPV) has been identified as one of the more promising routes towards the more widespread use of PV in the UK. A detailed consultation exercise with industry in 1996 identified a number of areas for further work on BIPV:

- the need for tested and certified PV building products which are acceptable to the architectural profession;
- improvements in designer's and specifier's knowledge of PV system design, including the development of design tools;
- optimisation of the benefits of PV including the development and validation of systems which improve the overall energy balance of buildings;
- increased number of high profile built examples demonstrating a balance of innovation and best practice;
- production of information material, publicity and marketing strategies which will be developed at appropriate stages of the programme.

As a result of the above, the following broad objectives were formulated to address the specific areas of further work identified:

1. to encourage innovative research into, and the development of, PV building products and to improve the buildability of PV cladding systems including the establishment of testing and certification procedures.
2. to improve understanding of the integration of PV systems into building energy strategies to minimise energy consumption and dependence on fossil fuels.
3. to develop guidelines and design tools for the building industry.
4. to demonstrate PV technologies in a range of building types and disseminate the knowledge gained from the design, construction and monitoring process.
5. to encourage dissemination, information exchange, publicity and marketing of PV as a building component to home and export markets.

The results of this consultation have influenced the projects supported by the programme. (It should however be noted that this focus on BIPV is not to the exclusion of other applications or aspects of PV.)

Guides and Information

A number of studies have been undertaken or are underway exploring some of the key issues relating to the integration of PV into buildings. These have covered the following areas:

- Survey of Tools for the Design of Photovoltaics Power Systems in Buildings[8]. This concentrates on the available computer packages for the design of PV systems and makes a detailed assessment of those tools available on the market.
- Guidelines for the Testing Commissioning & Monitoring of PV Power Systems[9]. This guide covers the design of a PV system for the facilitation of testing, commissioning and monitoring, procedures, handover documentation for PV buildings with pro-formas included in the report, and guidelines for performance monitoring.
- Planning a PV Building - Guidance for Designers[10]. This aims to provide mainstream building professionals with the necessary information to assist in the planning and preliminary design of PV for new build projects.

- A Study into the Planning Issues Relating to the Integration of Photovoltaic Power Systems in Buildings[11] in consultation with a number of interested bodies including RTPI, the Urban Design Group, the Civic Trust, the House Builders Federation and RIBA.
- Construction (Design and Management) Issues Relating to Building Integrated PV. The compilation of this report is being undertaken by BSRIA to assess the implications of the Construction (Design and Management) Regulations 1994 for BIPV systems.

The first four guides are currently available and at the time of writing, work is well underway to produce the other. It is hoped that the production and dissemination of this series of guides will improve the awareness of PV and promote best practice, leading to an increased number of good quality, well designed installations.

BIPV Development & Assessment Projects

One of the most tangible expressions of recent achievements is the built example of PV building integration. These are few in number at the moment and not all have directly benefited from government support although the research and experience accrued through the Programme and made available to the industry has contributed to their success.

This support has included assistance in the design phases of the project and monitoring of performance following construction. The objectives of Monitoring and Assessment projects vary in detail between projects but generally include the following:

- The sizing, selection and design of the PV system and its integration into the building envelope.
- Construction, integration with the utility grid, testing and commissioning.
- Monitoring of the PV output and other measured parameters.
- Evaluation of performance, cost effectiveness, reliability, customer satisfaction etc.
- Reporting and information dissemination

The following is a selection from projects which are or have recently been the subject of Monitoring and Assessment projects:

Oxford House

This house is owned by Dr Sue Roaf of Oxford Brookes University and is often referred to as the Roaf House or Oxford Solar House. The south facing roof incorporates 48 modules in a $4kW_P$ array[12]. The aluminium section includes drainage and condensation channels and is deep enough to ensure ventilation to the back of the modules. The house also contains many other interesting low energy features and Sue Roaf uses an electric car charged from the PV system. Monitoring took place between September 1996 and September 1998[13]. The array efficiency was shown to be 10.6% against a design value of 13.6%. The system produces 3039 kWh per year.

Ford factory

This is currently the largest PV power system in the UK. 26 rooflights covering 25,000 m^2 have been retrofitted to the existing roof of the factory. Each rooflight has clear glazing on the north side while the south side is covered by about $4kW_P$ of large area laminates giving a total capacity of 100 kW_P. The project was funded by the Ford Motor Company as part of its 'Factory of the Future' programme, plus DTI and the EC Thermie programme.

University of Northumbria

The University of Northumbria building is one of the earliest large scale examples of BIPV in the UK. The 1960s building's southern facade has been reclad using PV modules angled slightly from vertical to maximise winter output. The 456 modules have a capacity of about 40 kW_P. The project has been the subject of much publicity and is a landmark in the development of BIPV in the UK. Key results have been reported[14].

Doxford Offices

This prestige office development has been designed by Studio E Architects for Akeler Developments. The 73 kW_P facade is the largest in Europe and is estimated to produce 55,100 kWh per year. The design of this building was the subject of a paper[15] at this conference last year.

Equinox Building, London

Akeler Developments Ltd. plan to build a 300,000sq.m development on the old Alfa Laval site adjacent to the M4

in Hounslow with a south facade incorporating more than 2000m^2 of PV cells (around 194kWp). The PV facade will be the largest in the UK and will use a new glued structural double glazing incorporating the PV cells. The office development has been designed to be the first low energy fully air-conditioned building in London.

BIPV Design Studies

Design studies provide a means for learning about the design of building for the successful integration of PV but without the expense of actually proceeding to construction. There is a small series of around eight design studies underway. All these studies are based upon the designs for real buildings that are either currently being designed or were recently designed or are subject to a major refurbishment. The general aims of such studies are to consider the following:

- Design - identify the ways that PV influences the design process
- Power Output - matching of the output to diurnal and seasonal demand
- Costs - estimate the costs and benefits of integrating PV into the building
- Building performance - design may affect building form and shading
- Aesthetics - PV may form a very visible feature on a building

The findings of these studies will be integrated into a coherent set of findings and will be published later in the year.

New Initiatives

Mr Battle, the Minister for Energy, announced three new initiatives in the Solar PV Programme Area in February 1999. In summary the three initiatives are:

1. A field trial programme for 100 domestic installations. The aim of this experimental project would be to test a variety of PV installations under UK conditions.
2. A call for proposals for the development of PV components and systems. The aim of this call is to support the development of hardware and this would include products and systems specifically for the BIPV market.
3. The design of a potential scheme for demonstrations of PV in large-scale building-integrated applications. This idea is still in its relatively early stages but aims could include the establishment of best practice and acting as a showcase for UK technology and design. The aim would be to fund around 5 projects a year including a proportion of the capital cost as well as a contribution to the design, monitoring and evaluation of each project.

The call for proposals has been successfully concluded and the other schemes are in the process of further definition and development through a broad consultation including the building and PV industries and their representative bodies. The final form of the schemes will be subject to the final outcome of the governments review.

CONCLUSIONS

Renewable energy use in the UK has more than doubled since 1990, but the UK government hopes to achieve further substantial growth by 2010 and beyond. Renewable energy is playing an increasing role in energy supply but it will continue to be introduced via a wide range of technologies and time scales depending on local circumstances. The integration of PV into buildings can make a contribution to the energy sustainability, functionality and appearance of buildings, particularly if projected reductions in cost are realised. Supporting activities for BIPV in the DTI New and Renewable Energy Programme are helping to prepare the way for the more widespread application of BIPV through the provision of information and development of data and experience. BIPV costs will need to reduce significantly before the technology can compete with conventional fossil fuels and some other renewable energy resources (electricity generated from PV is typically an order of magnitude more costly than from conventional sources). However unlike many other generation options, PV can be readily incorporated into the urban context and generate power at the point of consumption. The PV industry continues to work hard towards steady cost reductions and this together with the strong environmental signal which PV provides should see the increasing use of the technology.