The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Photovoltaic Contribution to UK Electricity

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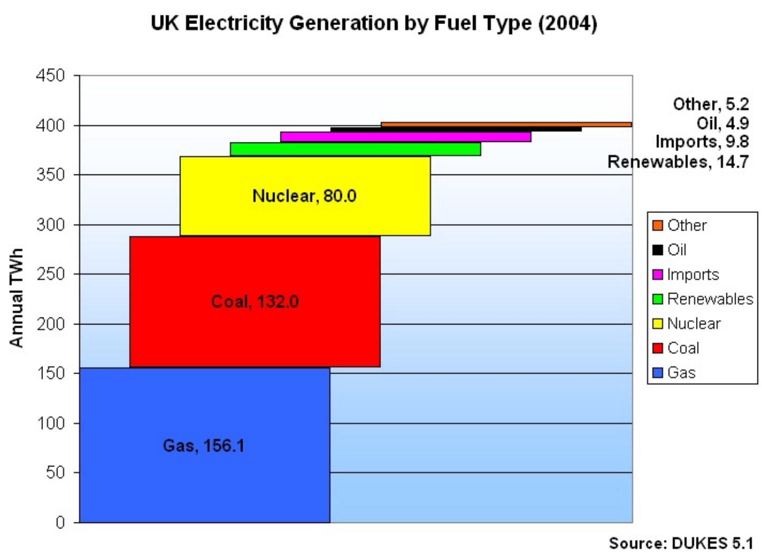
What role could photovoltaics play in the future energy mix of the UK? I believe our most pressing energy challenge is electricity and gas for lighting, heating, cooking and communication rather than oil. For this reason it's worth considering anything that can reduce gas burn for electricity generation which in turn either reduces imports or frees up more gas for more efficient use directly in the home. Photovoltaics are one such way to displace gas from electricity generation.

Just to get the perspective on this we need to review the current situation. Today we use some 400TWh [1] of electricity per year, generated from the following fuel sources:



Click to enlarge

The 156TWh of gas fired electricity generated in 2004 required 339TWh [2] (or 31 billion cubic meters) of gas, so UK gas power stations would appear to be 46% efficient on average. This gas burn represents 30% [2] of the national total gas use.

Our target for this exercise is to evaluate the feasibility or otherwise of hypothetically replacing half of that, some 78TWh with electricity from photovoltaics and therefore freeing up some 170TWh of gas. This would result in photovoltaics providing about 20% of UK electricity consumption, a similar amount to nuclear today.

Whilst the output from photovoltaics is variable I am not too concerned about integrating this supply into the grid. Although variable it is highly predictable a few hours in advance so a combination of managing fuel burn at remaining gas and coal fired power plants and shaping demand around this variability should be relatively simple.

According to a text book [3] I have here the annual insolation in the UK is approximately 1MWh per square meter of optimally tilted but fixed panel. This then leads to 1,120,000,000 square meters or **1,120 square km** of 15% efficient photovoltaic panel being required to deliver the required electricity to meet our hypothetical target. I'll use 15% as a typical polycrystalline cell and a compromise between the more efficient monocrystalline and less efficient thin film cells. Under standard AM1.5 insolation (1000 watts per square meter), such an area would have a **peak capacity of 168GW**.

These numbers raise a few questions, namely is there room in the country to accommodate such a deployment, could it be built and how much would it cost?

There are several ways to think about the area required; the 1,120 square km above represents 0.5% of the total land area. That figure isn't very illuminating so maybe it helps to compare it to other things. Roads take up 0.9% [4] or inland water 1.3% [5]. Alternatively the area could be considered on a per capita or per house bases. With 60 million people living in ~20 million houses the area works out as 56 square meters per house or a little under 20 square meters per person.

I would suggest the figures above are within the realms of possibility and could be met through a mixture of a dozen or so large industrial solar arrays of a few tens of square km and significant distributed deployment on buildings.

This is a photo I took last year at BedZed showing the photovoltaics in the upper windows with the dual purpose of generating electricity and providing shade. Click to enlarge.

Secondly cost. According to Wikipedia "As of early 2006 average cost per installed watt has decreased from $6.00 to $4.50" [6]. Not a great source but probably accurate enough for this purpose.

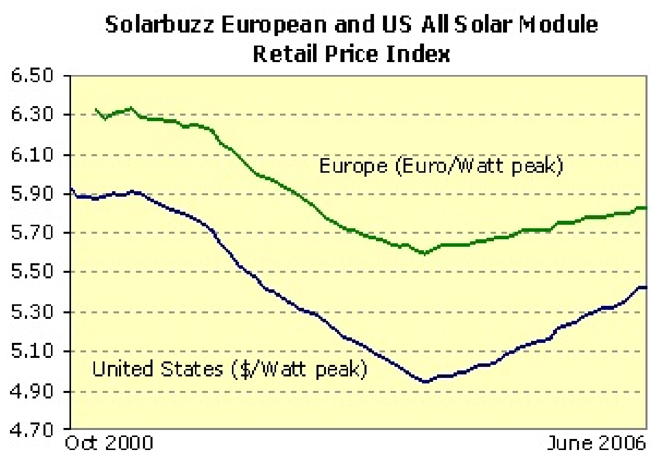
Multiplying by the required 168 peak GW installed capacity results in a **total cost of $756bn or £410bn.** That figure represents ~42% of UK annual GDP, some £6,800 per person or £20,500 per household. Oh dear. To persist with this just a little longer however, it is unrealistic to consider financing this all in one year.

One way of looking at this figure would be to finance it in a similar way to other capital intensive projects. Paying £410bn over 25 years (typical useful life of the solar panel) at an interest rate of 8% reduces the **annual cost to just £38.5bn** (or £29bn at 5%). This figure looks a little more reasonable, but how does it compare with other sources of energy in the future, specifically the gas whose import we are attempting to mitigate?

At current prices of approximately 2p/kWh [7] the 170TWh we are attempting to mitigate would cost £3.4bn per year. **So photovoltaics are currently approximately 10 times more expensive than gas.** Prices did spike to 5 and even 6p/kWh last winter, looking 15 or 20 years forward it's not unreasonable to suggest imported gas could be far more expensive than it is today, a three-fold increase taking the average price up to the spikes we experienced last winter would leave the current photovoltaic price less than four times as expensive.

Whilst gas prices are only going up, improved panel efficiency, manufacturing technique improvements and the economies of scale involved in manufacturing and deploying so much photovoltaic infrastructure are sure to reduce costs. To become cost competitive against this expensive imported gas the cost would need to fall to close to $1 per peak watt.

According to a graph at Solarbuzz [8] the costs of system installs have fallen at a rate of approximately 7% per year from 1996 to 2002 in Japan at least, yet retail prices of panels from 2002 to today haven't been falling so fast. In fact recently they have been rising:



Source: Solarbuzz

If optimistically prices fell by 10% per year it would take 20 years to get down to $1 per peak watt.

The final point on feasibility is manufacturing volume. Globally photovoltaic **manufacturing has been growing at 20-25% over the last 20 years**. In 2001 350MW were sold, rising to 557MW in 2003 and 927MW in 2004 [9], perhaps a growth rate of at least 30% is a reasonably expectation. We are talking about installing 168,000MW though or 6,720MW per year for 25 years. Global manufacturing capacity is unlikely to reach that level for another 6 years let alone indigenous manufacturing capacity. Indigenous manufacturing would bring secondary benefits of spending the money internally, stimulating the national economy rather than sending the money abroad, ballooning the trade deficit and the increased security of supply over reliance on imported gas involves.

With these assumptions, significant photovoltaic contribution to the electricity supply appears competitive in the medium term against imported gas and obviously in the long term imported gas won't be available at all. However it seems impossible to mitigate any meaningful amount of North Sea depletion over the next decade or so with photovoltaics.

I didn't know how the numbers would fall out of this when I started and whilst they aren't much more than order of magnitude accurate I expect the outcome is reasonable.

In conclusion I think there is the physical space in the country for such a photovoltaic deployment yet they are unable to generate a significant proportion of today's current power consumption due to high cost and limited manufacturing capacity. However that does not mean photovoltaics will never contribute a significant proportion of UK electrical energy.

The numbers are heading in the right direction. In a low energy future, perhaps consuming less than a third of the primary energy we do now and photovoltaic costs falling dramatically (and perhaps moving away from crystalline technology, towards thin film evolutions and onto organic cells) photovoltaics could provide a significant contribution later this century.

It's worth noting that Spain and Italy are also heavily reliant on imported gas, so too would benefit from a partial gas to photovoltaic switch. Their annual insolation is 35-100% more then the UK depending on location, improving the above calculations by that amount.

[1] DUKES 5.1

[2] DUKES 4.1.1

[3] Renewable Energy, Godfrey Boyle, 2004

[4] SABRE

[5] Wikipedia UK

[6] Wikipedia Solar Panel

[7] National Grid

[8] Solarbuzz Japan

[9] Solarbuzz Growth