2020

A vision for UK PV

An up to date and accurate analysis on the investment case for solar photovoltaics (PV) in the UK

UK Photovoltaic manufacturers association

www.uk-pv.org

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Introduction

This paper contains what we believe to be the most up to date and accurate analysis on the investment case for solar photovoltaics (PV) in the UK.

PV in the UK is sometimes seen as a technology which will only ever have niche application, and so not a core focus for energy policy. In fact, there is a wealth of robust, transparent data which strongly implies the opposite view – broad potential application and strong drivers for take-up.

In this document we set out three main pieces of analysis on PV's future potential in the UK:

Absolute **resource potential** for building mounted PV **Costs**, now and future, per watt-peak and per watt-hour (levelised costs) The timing of **grid parity** and associated investment case for different customer groups (homeowner, enterprise, investor and government)

We also explicitly draw attention to reasons for any discrepancies between the data presented here and that in other well-known industry views.

This paper is about the medium- to long-term potential for solar PV in the UK. To reach this potential, short- to medium-term market enablers (such as a feed-in tariff) will be required; although we have explored the case for these in a great deal of detail, we have set this out elsewhere as they fall outside the scope of this study.

Finally, we firmly believe in the potential of UK solar PV – alongside, not instead of, other energy efficiency and renewable energy technologies – and we predicate the future of our business on this potential. As such we obviously have a vested interest in the success of the industry. However we also have a great deal of knowledge about it, and by setting this out transparently and openly, we hope to contribute constructively to the energy policy debate, which will affect us all.

UK-PV
March 2009

Executive summary

Absolute resource potential for solar PV in the UK is 460 TWh for building-mounted PV. Ground mounted PV would add to this further. Absolute potentials for a given technology are to some extent abstract figures, because it makes much more sense to mix technologies and to use each to their maximum benefit. But this value is a fair comparator to the equivalent metric for other technologies, and is higher than usually stated for PV.

The electricity consumption of the UK is around 400 TWh, so even a fraction of this absolute potential would represent a substantial contribution to decarbonising, particularly since electricity is a high grade form of energy and so more carbon-intensive at the point of consumption.

Our figure for south-facing roofs and facades is 140 TWh, which ties closely to other industry estimates.

Costs per watt peak, approaching £4 per Wp installed now and below £2 per Wp installed by 2020, are falling rapidly today as recent constraints in the upstream PV supply chain unwind. Beyond this, PV has a long-term cost-down prognosis, driven by the nature of the manufacturing process for crystalline silicon PV and also by substitution to thin film.

Levelised costs per watt hour, at £80-£230/MWh by 2020, will be cost competitive with other energy technologies and lower in absolute than often stated, even where levelised cost modelling discounts the future output of the PV.

Grid parity will occur in around 2013 for residential customers, and around 2018 for commercial installations, based on current projections. PV grid parity is usually assumed to happen beyond 2020 in the UK.

Generally there is a good and ever improving investment case for solar PV, particularly at the residential level; PV is an investment grade technology due to its long life, reliability and predictability, and is seen as a valuable and low risk asset class for investors of many different types.

Solar roofs, Rotherham, South Yorkshire

Absolute resource potential for solar PV in the UK

Solar PV can be mounted on buildings, or racked in open land. We agree with the consensus view for the UK that using existing built-upon land makes more sense since where land is at a premium; as such we focus almost entirely on building-mounted potential.

Buildings

We define absolute potential as the energy output achievable from mounting PV on all available building structures.

The calculation shown in Figure 1 below sets out our view of absolute potential, based on the 4,000 available km^2 of roofs and facades on UK buildings[1]. Additionally, rather than use theoretical PV efficiencies we have used outputs observed in field trials, and we have de-rated this output where required to allow for orientation of PV (i.e., not south facing, or not angled optimally towards the sun).

The absolute potential, based on these assumptions, is **460 TWh**, 116% of current UK electricity consumption[2], substantially higher than assumed in most equivalent studies, and equivalent to 27 Severn Barrages or 19 Drax coal-fired power stations[3].

To some extent absolute resource potential is an abstract figure. We do not necessarily believe that take-up of this potential is a likely, or even sensible outcome – it would not be using PV to its best advantage (quite apart from making for a homogenous built environment), nor taking advantage of the full range of renewable energy and energy efficiency technologies available. However, an absolute potential figure should be exactly that, and as such this is the fair value for PV.

A more sensible potential figure might be **140 TWh**, 35% of consumption, based on south-facing roofs and facades only. This figure roughly agrees with estimates of the maximum reasonably available on buildings by Mackay (2008)[4], of 111 TWh, and IEA (2002)[5] of 105 TWh, both based on south facing roofs only. Note however that much of the de-rating, e.g. from tilted to flat or from south to east or west facing, is minor – as noted with respect to tilt in Mackay's analysis – and as such the "sensible potential" figure could arguably be higher than south-facing only, e.g. the E-S-W arc figure of **374 TWh**.

Clearly there are other downside considerations (e.g. shading) and upsides (e.g. improving efficiencies of PV, new builds designed with PV in mind). But the key point is that even the lowest of these potential figures would represent a substantial contribution to the UK energy mix and to addressing renewable energy and carbon targets, not least because electricity is a high grade form of energy and therefore particularly carbon intensive at point of consumption.

Ground-mounted PV

We have not focussed on the potential for ground-mounted PV in the UK; however, if it included, it would provide very substantial further absolute potential: 407 GWp for each 1% of the UK's land area. This would generate **346 TWh** per year, since ground-mounted PV can be optimally orientated.

Figure 1 – Absolute resource potential, UK building-mounted PV

UK building-mounted solar photovoltaic potential

Note this calculation shows the absolute resource potential for solar PV on UK buildings

It is more likely that a 'useful resource potential' is represented by the south facing or south, east and west facing subtotals as PV is deployed most cost effectively here

Assumes equal proportions of buildings facing approximately south (SE-SW), east (SE-NE), west (SW-NW), and north (NE-NW)

Data tables shown below

	Area km^2	GWp	Adjustment for pitch and azimuth	TWh/yr	% of UK electricity consumption
South facing domestic roofs	549	92	100%	78	
East or west facing domestic roofs	1,099	183	82%	127	
North facing domestic roofs	549	92	58%	45	
Total domestic roofs	**2,198**	**366**		**250**	
South facing other roofs	259	43	88%	32	
East or west facing other roofs	519	86	88%	64	
North facing other roofs	259	43	88%	32	
Total other roofs	**1,037**	**173**		**129**	
South facing façades	299	50	71%	30	
East or west facing façades	598	100	50%	42	
North facing façades	299	50	20%	9	
Total façades	**1,197**	**199**		**81**	
Total all building-mounted	**4,432**	**739**		**460**	**116%**
Subtotal - south facing only	**1,108**	**185**		**140**	**35%**
Subtotal - south, east & west facing only	**3,324**	**554**		**374**	**94%**

Reference points		
Metric	TWh/yr	
Actual/forecast output		
Current UK PV output	1.3E-5	(13 MWh)
Current German PV output	4	
Element Energy forecast UK take up	14	2020 after 10 years of 40p FIT
Consumption		
UK electricity consumption 2008	400	
UK energy consumption 2008	2700	Electricity, heating, transport
Other sources		**Key assumptions:**
Mackay, 2008	111	South facing, roofs only, 10m2 per person
IEA, 2002	105	South facing, roofs and facades
ETSU, 1999	266	All compass points, 1999 efficiencies
All PV potential		
PIU 2002	263	Unknown
Mackay 2008	1205	Cover 5% of land area in farms

Data tables

1. Available building space	England	UK	Source:
2007 population, m	51.1	61.0	National Statistics
Total land area km2		244,000	
Domestic buildings km2	1,508	1,800	Generalised land use database 2005
Other buildings km2	869	1,037	
Total buildings km2	2,377	2,838	
Ratio pitched roof area : plan area		1.2	Trigonometry
Domestic roofs km2		2,198	
Other roofs km2		1,037	
Total roofs km2		3,235	
Ratio façade area : roof area		0.37	IEA 2002
Domestic façades km2		813	
Other façades km2		384	
Total façades km2		1,197	

2. PV output			
Azimuth	Pitch	% of maximum	Source:
South	Horizontal	88%	PV GIS - this is a database of the relationship between incoming solar intensity and output of modules at different locations and orientations across Europe. It is based on both fundamental physics theory and field evidence
	35 degrees	100%	
	Vertical	71%	
East/West	Horizontal	88%	
	35 degrees	82%	
	Vertical	50%	
North	Horizontal	88%	
	35 degrees	58%	
	Vertical	20%	
Typical m2/kWp of PV module		6	Manufacturer datasheets, field trials
UK average PV output, kWh/kWp/yr		850	Field trials, BRE, Element Energy, PV GIS
kWh/m2/yr		142	
Wh/m2/hr = W/m2		16	Reconciliation of observed data to theory
Observed efficiency		16%	

PV cost reduction

Considering the future cost of energy technology involves two steps – the forecast per watt-peak (i.e. cost to manufacture and install each unit of the technology), and the levelised cost of energy produced per watt-hour (i.e. the sum of capital, operating and fuel costs, divided by the expected number of units of energy it will produce, over the technology's lifetime).

PV costs per watt-peak (Wp)

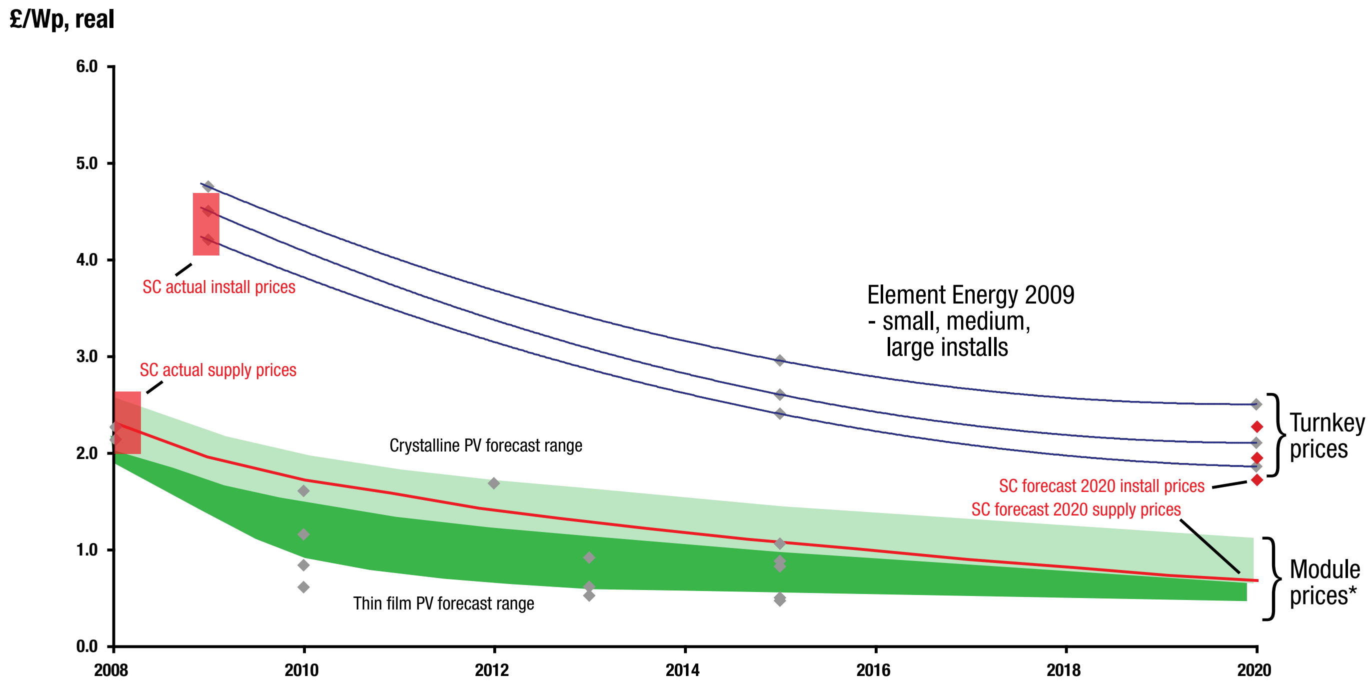
Element Energy, contracted by DECC/BERR, have modelled PV costs in the UK for large, medium and small installations as falling from **£4.2/Wp-£4.8/Wp today to £1.9/Wp-£2.5/Wp by 2020**[6], as part of their work looking at the potential for subsidy schemes for UK renewables.

We have tested these figures against our own commercial experience, and against forecast PV prices by a wide range of industry players and analysts (figure 2). Most PV forecasts are at the module level rather than installed, so we have used this to give a baseline of industry costs to 2020; we then come to our own view of 2020 installed prices by building other system costs on top of this.

There is currently an industry wide drop in PV prices of c. 20% over a relatively short time period[7], as a well understood and long-standing bottleneck in upstream PV supply unwinds. As a consequence of this the price of PV installations is also dropping, as seen in our own prices, and are slightly lower in 2009 than Element Energy's figures.

The long term cost-down potential of PV, inherent in a manufacturing process which is extremely scalable, supports Element's 2020 figure; substitution to thin film may make it even lower. Our forecasts for installed PV in 2020 are slightly lower than Element's.

Figure 2 – PV cost per Wp, now and forecast



* Red line is SC view – assumes steady substitution from crystalline to thin film, from 5% in 2008 to 30% in 2020.
SC view of turnkey prices shown in red.
Other sources: Solarcentury actual 2008-9; Deutsche Bank 2007; Merrill Lynch 2008; Rogol/Photon 2008; Greentech Media 2009; IEA 2008; ENF 2008; Element Energy 2008/9; First Solar 2008

PV levelised cost per kWh versus other technologies

Our modelling suggests a levelised cost for PV of **£80-£230/MWh in 2020**, comparable with several competing technologies. Element Energy's figures give marginally higher values, c. £85-£240/MWh.

The range given above reflects discounting treatment in the levelised cost calculation. Some studies discount the system output over its lifetime as well as the operating costs; others do not, on the grounds that discounting is essentially a financial measure and a unit of electricity does not have an associated cost of capital like a unit of money[8]. Another argument worth noting is that while most studies discount at typical commercial costs of capital (say 8% to 10%), some argue that levelised cost of energy calculations should assume public sector or utility discount rates, usually much lower (e.g. 3% to 5%). By virtue of its longevity, PV is particularly sensitive to discounting, hence the breadth of the range quoted.

Nevertheless, even in the fully discounted case, 2020 PV levelised costs of near £200/MWh are half as much as projected those projected in Ernst & Young (E&Y)'s 2007 study for BERR[9], and competitive with many other renewable technologies. In undiscounted cases (same treatment across technologies), PV becomes competitive with most energy technologies, renewable and otherwise, well before 2020 (e.g. Lazard 2008[10]). Figure 3 (below) details our assumptions on the levelised cost for PV by 2020, as well as the assumptions and conclusions behind the E&Y and Lazard analyses.

We also note that a separate 2009 E&Y analysis details substantial increases in wind and nuclear install costs over the past year[11]. Once again, while other renewable and traditional energy costs are on a long-term upward trajectory – due to fuel prices, but also maintenance, and the steel and concrete that make up much of the capital cost of any large plant – PV costs have a solid long-term cost reduction story.

Finally, there are other upsides to PV not modelled here – e.g. the cost of displaced building materials – but we would also like to reference the fact that in real-time pricing electricity markets, PV's predictability is again valuable – some studies have quantified this, and indeed rank PV as the most cost effective generating technology as a result[12].

Figure 3 – levelised costs of PV

2020 levelized cost of PV	
Input	
PV 2020 capex £ / kwp	1726
PV 2020 opex £ / kwp / yr	16
Lifespan, yrs	30
Cost of capital	9%
kWh / kWp	850
Output	
Cost £ / MWh (actual output)	**81**
Levelized cost £ / MWh (fully discounted)	**228**

Sources: SC analysis, Element Energy, PV GIS

Reference points

Ernst & Young 2007 - PV in 2020	
Input	
PV 2020 capex £ / kwp (mid range)	3675
PV 2020 opex £ / kwp / yr (mid range)	35
Lifespan, yrs	25
Cost of capital	15%
Capacity factor	16%
Output	
Cost £ / MWh (fully discounted)	**444**

Lazard 2008 - PV today (US analysis)		
Input		
PV 2010 capex $ / kwp	6325	
PV 2010 opex $ / kwp / yr	25	
Lifespan, yrs	20	
Cost of capital	9%	
kWh / kWp	1450	assumed - Sunbelt
Output (calculated)		
Cost $ / MWh (actual output)	**118-168**	

Ernst & Young 2007 - other selected technologies in 2020	
Onshore wind	61-83
Offshore wind	85
Biomass	95-139
Wave	151
Tidal	137

Lazard 2008 - other selected technologies today	
Wind	47-69
Biomass	50-94
Nuclear	74-80
Gas Combined Cycle	73-134
Coal	74-135

Other factors driving PV adoption

Ultimately a low cost is the primary driver of take-up of any energy technology by any category of purchaser. However, there are other advantages specific to PV that have helped to drive its rapid growth globally over the past few years, and which we believe will continue to do over the long-term.

Individual homeowners and businesses

Convenience: PV is an low maintenance and reliable technology. It is warranted as standard for 25 years, needs minimal service over this period, and operates silently with no moving parts.

High aesthetic: PV can be integrated into the building fabric itself . Solar roof tiles and slates, cladding, and other building-integrated uses are becoming more and more commonplace, and can be used either to enhance a building's aesthetic, or in a subtle and unobtrusive way.

Asset value: the investment case for microgenerating technologies is greatly enhanced if they retain their value when integrated into a building. There is solid and growing evidence that PV is one of the better technologies from this point of view, largely as a result of the characteristics mentioned above[13].

Investors

Predictability: solar PV is widely considered an "investment grade" technology by funds – its reliability and the predictability of its output is ideal in underpinning cash flows and associated financing at a low risk to the investor. "Cleantech" has been a key growth sector in recent years, and solar the fastest growing within this: the sector attracted $150bn, 10% of all global investment, in 2007, around $30bn of it in solar[14].

Government

Job creation: by virtue of its suitability for building integration, PV creates more jobs than other technologies, in installation as well as manufacture of products suitable for local construction markets. UNEP estimate PV job creation at 7 to 11 per MWp installed[15]; this figure is supported by the German solar experience, where over 50,000 jobs have been created since 2000[16].

Carbon targets: all renewable energy and energy efficiency technologies have a role to play in carbon reduction. PV is particularly strong as it generates electricity, a high grade of energy, and can do so at a local level, thereby displacing more carbon per watt installed than centralised or heat based technologies.

Solar roof tile installation, Melton Mobray, Leicestershire

Grid parity

Grid parity is the point where electricity output from a PV installation over its lifetime equals the cost of an equivalent amount of grid-sourced electricity. This can be calculated by modelling the declining cost per unit of PV against the inflating cost of grid electricity, shown in figure 4 below.

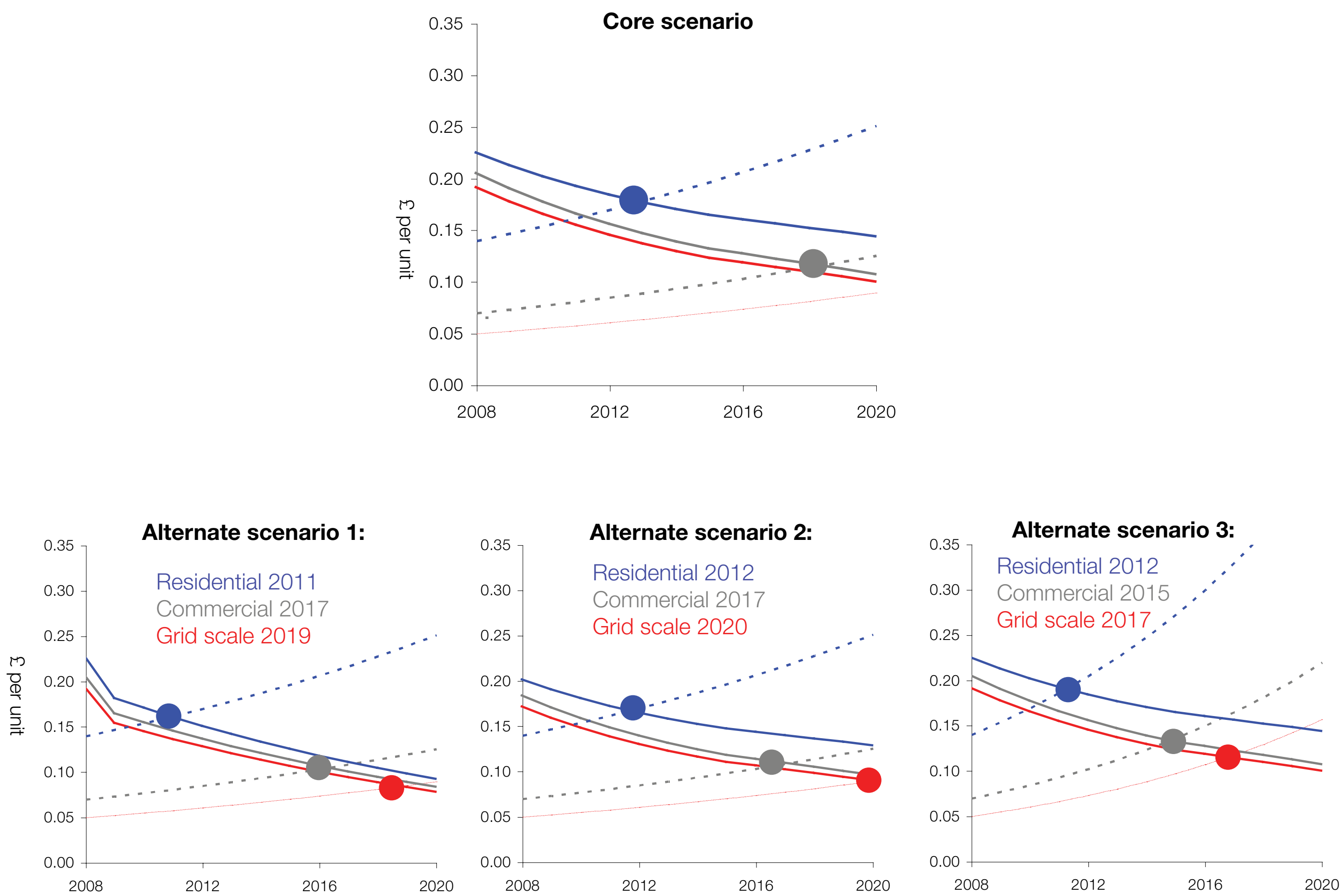
Parity occurs at different points, depending on the end customer. Residential customers purchase expensive retail-priced electricity, so parity happens earliest for this category – in the UK, we believe, as soon as 2013. Since PV is one of the few genuinely scalable renewable technologies, working as well on houses as in larger installations, this proximity to parity heralds the prospect of PV being a compelling investment for the individual, without subsidy, in only a few years time.

For commercial customers and even at grid generating scale, where electricity is at wholesale rates or less, parity is still likely within about ten years even with conservative assumptions. This is much sooner than most forecasts suggest.

Although grid parity does not necessarily mark the point where investment in PV becomes completely self-sustaining – since different customers have different investment timescales – it does represent a change in an energy technology's positioning from niche to mainstream, and is an end goal of any subsidy scheme.

Figure 4 – grid parity in the UK

The diagram below shows falling costs of PV (solid line), rising costs of grid electricity (dashed line) and parity (solid circle) for each of residential (blue), commercial (grey) and grid-scale (red) electricity customers. The main analysis, and three variants, are based on the assumptions detailed below.



Grid parity data and assumptions

Input		Base scenario	Alternate scenarios
PV 2008 Installed prices £/Wp: (includes lifetime maintenance)	large mid small	£4.5 £4.8 £5.3 (BERR Renewable Energy Strategy, after Element Energy 2008; also LCBP2 figures)	
PV price declines		6% p.a. decline (BERR Renewable Energy Strategy, after Element Energy 2008)	**1.** Additional 20% one off price decline in 2009-10 (Current market supply situation)
PV lifespan / performance		30 years 0.6% p.a. module output decline 850 kWh/kWP (EPIA, PV-GIS, module manufacturer data)	**2.** 950 kWh/kWp in Southern England (PV-GIS)
Grid electricity prices: (2008 baseline)	cost; w'sale: retail:	5p/unit 8p/unit 14p/unit (BERR Quarterly Energy Prices,2008 median)	
Grid electricity inflation		5% (BERR, rises over last 10 years averaged; equivalent to 3% p.a. plus one off 30% spike)	**3.** 10% (Other supply crisis)

Solar facade, Manchester College of Art & Technology

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