The first 2 pages of this PDF comprise the article as printed in "Reforesting Scotland", the following 10 pages are the technical endnotes as referenced, and finally, a subscription form for this inspirational little journal of people-centred tree ecology. Enjoy!

Wood, wind and sunny Govan

After years of angst-ridden hand-wringing, Alastair McIntosh *has radically cut his domestic carbon footprint by combining a wood stove, solar panels and an air-to-air heat pump. Here, Alastair describes how he did it - and for the technically-minded reader, the numbers in the text link to further information on his website.*

In 2008, Birlinn published my book, *Hell and High Water: Climate Change, Hope and the Human Condition*. But my own domestic carbon footprint was frustrating. Now, thanks to technological advance and crashing prices, we are managing to reduce our emissions by well over half.

My love affair with renewables started in the 1970s, when I was volunteering in Papua New Guinea. A French priest, Fr Jean Besson, had been killed on his own airstrip before finishing a 20 kW village hydro system. With a crofting background from the Hebrides, I was given the young man's dream commission of getting it going. I will never forget the day we opened up the sluice and let the river flow ten metres down into a huge Francis turbine. As the flywheel hummed up to speed, I threw the switch and to the sheer astonishment of us all, the village lights came on in utter silence - without the usual diesel-guzzling racket.

Our carbon footprint

Since those halcyon days, I have had to make do with the hum of my bicycle dynamo. Vérène and I moved to Glasgow's Govan in 2004 to be with the GalGael Trust of which I am a founding director. Our single sop to renewables has been our low-emissions wood stove, fed from skip-diving and GalGael offcuts [1]. Now that has changed, but first, let me establish our baseline domestic energy demand.

We live in a hard-to-insulate Victorian end-terrace house, both working from home and typically spot-heating three rooms plus the utility areas to around 20° C. Partial external wall insulation would be nice but I have not yet managed to find a reliably certified company that can affordably take on such a one-off job – they all say "we might be getting into that next year"! Averaged over the past four years, our consumption has been 4,036 kWh (or units) of electricity per annum and 17,942 kWh (or units) of gas (converted at 11.3 kWh per m^3). The standard figures used for the carbon intensitivity of grid electricity in the UK is 0.525 kg/unit and that of natural gas, 0.184 kg/unit. On that basis, our annual carbon (CO_2) footprint is 5.4 tonnes, for which, all up, we pay £1,285/annum or £107/month [2].

The heat and light for a typical Scottish home of 2.18 occupants releases 5.8 tonnes of CO_2/annum [3]. How come we are just around the average when we work from home, often with meetings going on in the house, when the average is based on many people going out to work and perhaps not heating their homes during the day? It is the stove that cuts a tonne off the higher amount that our figures would otherwise show. Mind you, like all ecology it's a niche solution. If everyone in Govan went skip-diving we'd be having skip wars! [4]

Why not abolish the FIT system and legislate that energy providers must buy back at the same price as they sell?

The great cosmic woodpile

So, bring on what I now call The Great Cosmic Woodpile in the Sky - this magazine, remember, was originally called *The Tree Planter's Guide to the Galaxy*! The price of solar voltaic panels has crashed recently and so, in January 2013, we put in a decent-spec 4 kW system for just £5,000 fully installed [5]. That sort of price – even if a bit higher in rural areas - democratises solar. You can tell your neighbours that it is no more than a second-hand car.

Our system, which is on a south-southwest 35° tilted roof, should produce a little over 3,000 units/annum [6]. From January to June it has over-performed by 14 per cent - but hold on, this has been a cold but sunny spring in Glasgow, with sunshine hours 20 per cent above average. Truth is, we are running 6 per cent below par, which is probably largely due to shading from our wood stove's chimney! [7]

Assuming we produce 3,000 units/year on average, then three-quarters of our previous electricity demand will simply fall off the roof. Our feed-in-tariff (FIT) - both "generation" and "export" combined - is 17.69 pence/unit [8]. That offers some £530 a year, index-linked and tax-free, for the next 20 years. In addition, the FIT system assumes that you use half of what you produce yourself and only export the balance to the grid. If we can in fact use that in sync with when we are producing it, we will save a further £196/annum on our electricity bills. All up, it nods towards an investment payback period of just seven years. The internal rate of return is at least three times better than current life assurance annuity rates [9].

But here's the catch. Most frugal households cannot sustain using half of the solar power that a 4 kW system produces [10]. Our home baseload is only about 200 watts. Even in fairly heavy cloud, the panels provide that and so when the sun comes out, and our output shoots to well over 3 kW, we are giving away freebies to the grid except when the kettle's on. We buy electricity from the grid at 13.07 pence/unit but only receive a notional 4.5 pence/unit for selling 50 per cent of our production back to it. A good deal for our utility provider! Our previous carbon footprint for gas and electricity was 5.4 tonnes. Producing 3,000 units of clean green juice cuts that by 1.6 tonnes to 3.8 tonnes [11]. I therefore had a question. Could we raise efficiency - on both costs and carbon – by using our solar production more fully without being wasteful? [12]

Clockwise from top left: "Puffer", the indoors unit; 4 kW solar voltaic system on our house in the Drumoyne area of Govan; The Worcester Bosh air-source heat pump outdoors unit.

Air-source heat pump

I saw my first air-source heat pump (ASHP) at last year's Mull Renewables Fair [13]. They operate like a fridge or air conditioner running in reverse [14]. Instead of using high-grade (flexible) electrical energy as a direct means of heating, they use it intelligently, to move ambient heat around [15]. I reasoned that quite often Vérène and I would have the central heating off, but each have a wee 500 watt heater to keep the chill at bay. That kilowatt equates to what our solar can produce even just in bright cloud, so could we use an ASHP instead, and heat the house effectively?

New Guinea had been kind to us. We'd had a slice of well-paid work from West Papua on the Indonesian side and so for once could afford an experiment [16]. Costing just under £2,000, we installed a Worcester Bosch Greensource ASHP that typically runs at 1.2 kW and converts it to around 5 kW of heat [17]. It is like a perpetual motion machine come true. A fishbox-sized unit sits in our garden making a gentle whooshing sound from its fan. An ASHP can be a 'permitted' planning development but you should check out your situation as you may need permission [18]. It uses refrigerant gases, transfers atmospheric heat (even when it's freezing) to an indoor blower above the front door that we call "Puffer". From there, it wafts up to our offices and wherever doors are open [19].

Puffer also ionises and filters the air, removing dust and spores, and in summer can dehumidify and cool. We will still need the mains gas in winter, but since the start of April have only used it to heat water and that's with a mean temperature in Govan, according to Met Office figures, of only 7.0° C (more like the norm for March than April), just 7.5° in May and 14.0° in June [20]. Our previous energy costs for April-June were £286. This year they were only £142, less the solar FIT repayments of £243, yielding a net profit of £101. Meanwhile, our carbon footprint fell by 81 per cent, after allowing for carbon credit on what we exported to the grid. If that's not green magic, tell me what is! [21]

The NUB of energy policy

While the FIT has been a good policy to kick-start green energy, we live in an area of fuel poverty and don't like being subsided by neighbours. I therefore have a policy proposal. When our panels were first installed, our olde-worlde meter with its rotating dial ran backwards and unwound when exporting. Scottish Hydro had to change it. But what a wonderful system, because this measured our net usage. I suggest: why not abolish the FIT system and legislate that energy providers must buy back at the same price as they sell?

I would call this the NUB - the Net Usage Basis. Our electricity provider would let the grid be optimally used as a battery or bank. We would wash their dirty energy clean, and do so mostly around lunchtime when wholesale spot prices are at a peak. On such a NUB I calculate that, even using discounted cash flows, we are now touching the holy grail of grid parity for domestic systems [22]. For sure, it's niche. It all depends on your roof. Yet niche by niche new ecosystems grow.

Alastair McIntosh *is a Fellow of the Centre for Human Ecology and author of books including* Soil and Soul, Rekindling Community *and most recently,* Island Spirituality. *Additional information, including technical endnotes to this article, can be found at http://www.alastairmcintosh.com/articles/2013-RS-McIntosh-Solar-HP.pdf and with Alastair's full solar data at www.alastairmcintosh.com/general/energy/solar-heating.htm.*

Technical endnotes to Alastair McIntosh's article

Wood, Wind and Sunny Govan

(on solar panels with air sourced heat pump)

Reforesting Scotland, Issue 48, Autumn 2013, pp. 28-29

For solar data updates see: www.alastairmcintosh.com/general/energy/solar-heating.htm

To order or subscribe to the journal, *Reforesting Scotland*, see page at the back

[1] **Woodburning Stoves in Smoke Control Areas:** Several companies now produce small woodburning stoves that are DEFRA approved for smokeless zones. These include Morso, Aga, and my own beloved Charnwood Country 4 which is reckoned to have the biggest glass door in the 4 kW range and is rated at 83% efficient. It requires an optional add-on gizmo that renders it DEFRA approved by stopping it from being shut down to an extent that would cause the wood to smoulder and thereby fail on DEFRA's "snuff test" for what happens as a stove goes out.

[2] **Calculating our Domestic Energy Costs and Carbon Intensitivity**: This figure of £1,285 for our domestic energy costs is based on £528 for electricity at 13.07 pence/unit (including VAT) for 4,036 units and £757 for the gas at 4.22 pence/per unit for 17,924 units. On top of that, Scottish Hydro charge us 16 pence a day for each utility's standing charges, so that's another £117 on the bills, bringing our total to £1,402. Our domestic baseline data is here, and data and experience will continue to be updated on my website at: http://www.alastairmcintosh.com/general/energy/solar-heating.htm. Until a year or two ago we were on Scottish Hydro's RSPB Green Tariff. However, this was terminated – I believe it was an uneasy relationship given the wind farms v. birds and wild land issues. Existing customers were sifted to their standard tariff and I must confess I didn't get round to rethinking my supplier and am now tied in with the solar contract. I also confess that a good part of my not getting round to rethinking suppliers is my own ambivalence about the effect of massive wind farms on wild land, and the industrialisation of the countryside to justify not just social needs, but escalating wants.

My conversion factors for the carbon intensitivity of mains electricity in the UK and natural gas are drawn from the Carbon Trust's 2011 report (p. 3), *Conversion Factors: Energy and Carbon Conversions*. This assesses electricity as carrying an embodied carbon footprint of 0.5246 kilograms of CO_2 per kWh (or unit) and natural gas, at 0.1836 kg CO_2 of per kWh. While natural gas is metered in cubic meters (m^3) because it is delivered in volume, bills these days are charged in kWh of energy content and mine, from Scottish Hydro, use a conversion factor of 11.3059 kWh/m^3.

Note that the price ratio of electricity:gas is about 3:1, and this is almost the same as the carbon intensity ratio. Mains electricity is therefore both 3 times more expensive than gas and has a carbon footprint three times as great. This will presumably start to fall as renewables start to make up more and more of the energy mix and I have heard one suggestion that in Scotland now, because of the mix of nuclear and wind, the energy intensitivity of grid electricity may be down to about 0.3 kg/unit but my informant has not been able to confirm this. Either way, under the Scotland Act 1998 energy policy remains a power specifically "reserved" to the UK government in London therefore under the current political constellation, the "national" grid operates on a UK-wide basis (and may, in future, become more and more Europe-wide). The practical implication for this article is that for a heat pump running on a standard mains electricity tariff to be both cost and carbon efficient, it requires to be running at a COP (coefficient of performance) of at least 3:1. A 2010 study by the Energy Savings Trust suggests that this not achieved as much as it should and could be (see Note 14 below).

[3] **Comparing Domestic Energy Carbon Footprints**: That figure of 5.8 tonnes of CO_2 for heat/light in the average Scottish household comes from the 2013 Energy Performance Certificate (NHER EPC On Line v8.0 (SAP 9.91)). I've used it because I was finding difficulty locating a source. Sourcing data for an amateur like myself is a problem. In general, I find that much of the data that was put online in the run-up to the failed UN climate summit in Copenhagen in 2009 has not been updated, or the links have gone dead. (For example, when I tried to locate one report supposedly on the website of the UK's Sustainable Development Commission I drew a blank, but was given the sad message: "The Sustainable Development Commission, which closed on 31 March 2011, held Government to account to ensure the needs of society, the economy and the environment were properly balanced in the decisions it made and the way it ran itself. This is an archive site.") However, I have triangulated the 5.8 tonne figure that I have used via *Energy in Scotland*, Scottish Government, 2010, pp. 19-23. This gives the 2009 mean usage of electricity per household as 4,863 units and 13,000 units for gas. (The latter is a round figure because the report provided only a graph that could be only crudely read off). Applying carbon intensitivity conversion rates of 0.525 and 0.184 kg/kWh respectively,

this suggests a mean Scottish domestic energy carbon footprint from gas and electricity of 4,945 kg. How does that square with the 5.8 tonnes per household cited above? It guess it does so because, while nearly all homes are on mains electricity, not all are on mains natural gas, so you also have to factor in oil-fired heating, bottled gas, peat and coal that are used mainly in rural areas. On that basis, I am reasonably satisfied that the 5.8 tonne figure is reliable.

[4] **My Ten Top Woodpile Tips**

In our home we have historically (i.e. before getting the heat pump) put the gas central heating off at about six in the evenings and then light the stove in the living room. Post-heat pump we've been using less wood, but here's some tips.

1) It's "a good thing" to scavenge for wood because it's going to slowly revert to methane and then to CO_2 whether burnt or not. However, think twice about taking windfall from places where it might be needing it for biodiversity. Skips destined for landfill are best, but strictly speaking skip-diving is theft. Face your skip and solemnly ask: "May I take a dive?" If challenged, reply: "Yes, Constable. I asked permission and can assure you, it was not refused."
2) Clean your stove's glass if needed with wet tissue and a dab of ordinary kitchen detergent. If badly clarted up (usually due to wet wood, especially wet softwood), spray with oven cleaner or use a proprietary gel. Be wary of the old tip of using wood ash to clean the glass. It works, but contains silica which scratches, and I have found these modern fireproof glasses to be very soft.
3) If you have another primary source of heating, get a stove that's on the small size rather than the large size. It's more efficient and produces less smoke to burn heartily than to try and run it heavily damped down. If your stove is too big, put some bricks inside to make a more contained fire box and also serve as thermal storage for the night.
4) If the door lining rope has got compressed so that it clangs loosely shut, replace it so that air does not leak in at the wrong places. Leaks carry away your heat up the chimney and make it harder to control the blaze. You can buy lining at stove shops – which, like country ironmongers, are always very special places to visit.
5) If only ticking the stove over but not wanting to let it to go out, add as few as 3 nuggets smokeless coal clustered together to keep a heart in place. However, use high quality low sulphur material because, as a general rule, you shouldn't mix coal (sulphurous) with wood (moisture) because they make sulphuric acid that will reduce the life of your flue.
6) Wood from merchants can be too wet and it wastes energy boiling itself off. Logs should be seasoned for 2 years. Buy them in spring so that they can dry more over summer. Pack loose to let the breeze get in.
7) Plan your springtime usage so you don't reach the bottom until hibernating critters have had time to awaken. We get frogs, field mice and a swarm of wild bees making use of ours.
8) If going for a car run, offset carbon karma by scavenging. It's fun to calculate how much wood you need to offset the fuel. I base my calculations on what the wood will save by not having the central heating on. But watch out. DSM-5 classifies this as *Wood Nerd Disorder* which is grounds for divorce. Just imagine! She goes off with the stove and all you get is an unchopped woodpile.
9) If in France, buy a legendary *Leborgne Coin Éclateur* log splitting chisel wedge. It twists as you hammer to force the log open and is totally amazing for opening up knots. I bought mine in a village ironmonger's shop in the Cevennes. Pleading Scots exceptionalism I said to the stiff-looking matron du maison: "En Ecosse, nous avons un petit problem avec les sapins Ecossais" – to which she replied witheringly - "Everybody has that problem."
10) Logs are solid sunlight from a bygone age. That's why *Reforesting Scotland* used to be called *The Tree Planter's Guide to the Galaxy*. A woodpile is a spiritual practice.

[5] **Our Solar Panel Specifications:** We got our solar panels from Direct Solar, chosen not least because they've got a base just up the road from so I could go and hammer on their door if anthing went wrong. Buying panels at present is a bit like buying double glazing. You have to try and have your wits together or get experienced help. I had little access to either, but I checked them out on the web for complaints and only found one. My experience has been of good service. Consistent with MCS requirements (necessary to get the FIT) they had a roofing engineer check the roof and the panels were installed by roofers. Their office provided full documentation, arranged for our Energy Performance Certificate, and carefully went through my FIT registration form before it went in so there were no hitches. It took half a day for 2 roofers and an electrician to install the system. I can only say that so far, apart from slight losses due to overshadowing from our chimney that was not initially pointed out by the salesman (it was pointed out by their roofing inspector), "it does what it says on the box".

Some weeks after they'd been I noticed that a bit of pointing had fallen out from the eaves. I emailed and said, "I realise that some time has passed, but would you consider dropping by?" and they emailed back straight back saying: "…if there is any issues with your system or roof we will deal with it so just let us know. We would never say its 'nothing to do with us.'" Shure enough, they came round and fixed it – which impressed me more than if nothing had gone wrong.

I don't know the solar industry in Scotland enough to give Direct Solar an unreserved recommendation. You have to shop around in your part of the country and if I was in the countryside, I think if possible I'd be looking for a long-established local firm that's built a reputation worth not losing in other areas of business because outside of the city with all its choice you have to be far more switched on to the question "what happens if it goes wrong?"

We've got 16 Canadian Solar panels and the only disappointment was to find that this august-sounding brand was a marketing name for what were actually Chinese panels. A neighbour (whose example helped to prompt my action) paid about £1,000 more has Portuguese ones his company never responded to efforts to get a quote. His ones are solid black and therefore merge in better with his roof than mine which are the more silvery kind. Mine are monocrystalline (good for cloudy conditions), each 250 watt panel of dimensions 1638 x 982 x 40 (i.e. just under 30 m^2 covered), with a purported efficiency of 15.54% and connected in a single string to a Swiss-made SolarMax inverter. Reviews of Canadian Solar seem to rate their panels highly.

When we got our 4 kW system in January 2013 we paid £4,495 and the company were also offering a 2 kW system for £3,000 and 3 kW for £4,000. Just as I was completing this article in June they raised their range of prices across their range by £1,000. However, I have left my figures in this article as they were because, by googling, I see that it is still possible to buy a 4 kW system for around £5,000. (In fact, one company on the east of Scotland is now advertising a "budget" 4 kW system (whatever that implies) fully installed for £4,500). I asked Direct Solar why they'd put the prices up and they said it's to do with changes in how they import from China and because to conform with customer preferences, they now supply black panels as standard - also from "Canadian" Solar but costing more. My sense of what's actually going on is that we got in at the peak of Chinese dumping, and now that a deal has been struck between the EU and China we can expect to see a new and for a while at least, slightly higher price equilibrium settling in. Note that our prices are Glasgow prices. Talking to switched-on folks in the country who've recently had panels fitted they seem to have paid about one third more (from different companies) – and that doesn't surprise me given the added cost of coordinating rural tradespeople. I'd note, however, that if you're in the country and therefore without mains gas, having free power to put into a heat pump or even straight water heating is very beneficial, so you could make good your losses, so to speak.

My guess would be that prices in the short term will stay about where they're at but that in the medium term – say over the next 5 years – we'll be looking at domestic installed capacity at about £1 per watt. (Industrial-scale installations are less than half that.) I don't see it being able fall much below £1/watt for domestic because the lower the equipment prices fall (panels, roof fixing system, inverter, wiring and meter), the more the balance of costs shifts towards such less variable quantities as labour for installation, sales effort and the profit margin. Future improvements will probably be more in panel efficiency rather than falling installation prices. Already, the most efficient panels on the market are just over 20% efficient at converting sunlight into electricity. That's fully one third better than our panels, but at rather more than one third more to purchase! But it shows the way things are going. With such wizmo-gizmo panels our roof could generate 100% of our historic domestic electricity demand instead of just the anticipated 75%.

Our panels come with a 10 year product guarantee (5 years on the SolarMax inverter, optionally extendable to 25), and their power output is guaranteed not to fall below 80% after 25 years of use. These guarantees are presented as cast-iron, but I ask myself: if my fitter went bust, and Canadian Solar went bust, would I really be able to follow it up with the underwriters and get my money back? I suspect such guarantees are more important as indicators – indicative of what is pitched towards big industrial solar installations – than the likes of us. Linked to the question of warranty is insurance. It seems quite common that panels will be covered on buildings insurance policies. I phoned up our insurer, Direct Line, to make sure. They made a note that we had panels fitted, but said there was no additional charge for having them covered. I found that very reassuring since being Hebridean-raised, I don't trust anything attached to any roof in a Scottish gale. I also find it reassuring that quite a bit of solar is being fitted in the Outer Hebrides just now and I've not heard, yet, of any problems. I've also checked the web about storm damage to solar panels and I have to say, the main picture coming back seems to be that if anything (where properly fixed) they can protect a roof – I was struck by one picture showing the part of an American roof without panels ripped off, but the panel-covered part intact since the wind had flowed more readily over it.

[6] **Solar Output Estimates**: Expected solar returns can be estimated at this European Union website, which is widely considered to be state of the art.

[7] **Shading and Solar Voltaics**: Most people do not understand that shading from such things as the "eyebrows" of upper windows and projecting features, dormer windows, trees, lamp-posts or chimneys is a far more critical factor than intuition would suggest. The affordable type of solar panel that most folks get are connected in series in a string, or 2 strings if you have an east/west system. The capacity of any given string is limited by its weakest link. If one panel is in the shade, or tilted at an angle out of kilter with the rest, this is like putting a foot on a hosepipe and the performance of them all gets throttled. See a short demonstration video of this effect here. The severity of the problem is partly limited by having bypass diodes – ours have 3 per panel - so if, for example, only part of one of my panels is shaded, that will bypass and the effect on the whole string will be less heavily pronounced.

I notice that I get relatively poor performance from my panels when the sun first comes round from the east in the morning until the shade cast on a solitary panel from our chimney is clear. I've wondered if it would be worth removing that panel, but taken over the full day its yield probably justifies its losses. Avoiding shading is usually the main reason why, as you go around the country, you'll see panels put on some roofs in what look like rather unseemly configurations. Tilt also matters greatly. Around 35% (+ or – 5%) seems to be optimal for Scottish latitudes. I notice that in high summer our peak rate in full sun falls off to about 3 kW because the sun is too high to strike optimally, but we'll benefit in the shoulder season – when we most need the power, and in early May in full sun we were getting about 3.6 kW and that was without cloud-edge effect which is when the sun peers through a hole and transiently it shoots up to just over 4 kW because of getting not just the direct sun but also the reflected light.

It may also be that my perceived efficiency loss may not prove as great in the longer term than currently meets the eye. Our panels are monocrystalline and designed to perform relatively well in cloudy conditions. There may be a trade off in very sunny conditions. I notice, for example, an anomaly in my data by which in April 2013 sunshine hours were a whopping 35.3% above average but my panels were only 22.1% over. In May, however, sunshine hours were 1.3% below average but my panels showed an underage of only 4.6% (i.e. still under, but proportionally less so than in the very sunny weather). Bright sun may therefore have exaggerated my apparent losses, and I speculate – pure speculation – that this might be a side effect of monocrystalline panels which are optimised for cloudy conditions. (Ps. August 2013 has proven to be anomalous. My panels produced 23% over what would be affected, thus reducing the under-performance to date to only 3.89%. Met Office figures are initially provisional, but barring some big mistake at their end, which is most unlikely, I have no explanation for this shift. It may just be microclimatic variations between Govan and Paisley).

East-west configurations can give reasonable returns – apparently about 20% less than full south for the same number of panels but with the advantage that with the extended collection time from dawn to dusk you can make much better use of what you produce. In the absence of a NUB (Net Usage Basis) system, and running my heat pump, I would happily have an east-west system as that would pay me less on the FIT, but yield more free and carbon neutral energy for a longer period from which to run the heat pump.

[8] **Understanding Solar Feed-in Tariffs**: The solar Feed in Tariffs (FITs) come in two parts – a payment simply for generating clean energy, which you receive whether you make use of it yourself or not, and a payment for what you export to the grid. The justification for this is to stimulate the solar industry and encourage a social shift away from carbon intensive energy production such as drives dangerous climate change. Research suggests that the public are willing to pay more for clean secure energy supplies.

Back in April 2010 the "generation tariff" was a whopping 43.3 p/unit. On top of that was an "export tariff" of 3p/unit. Since on small domestic systems it is not worth measuring the precise amount exported the FIT system makes an assumption that the average producer will make use of half their own production and export the rest. As such, you got paid 43.3 p/unit plus half of 3 p/unit, the combined tariff at that time being 44.8p/unit.

Around that time one of our neighbours in Govan was quoted £22,000 for a 3 kW system. The tariff needed to be high to give an incentive. The sales literature she was given was based on optimal south of England locations and I advised her, even if she had the money (which she didn't), not to have anything to do with such a company.

By the time we picked up our £5,000 panels this January (2013), the generation tariff was down to 15.44 p/unit and the export tariff, up to 4.50 p/unit (up, because it is index linked, and energy prices had been rising). Our net combined tariff rate is therefore currently 17.69 p/unit guaranteed index-linked for 20 years. That is to say, you literally get given a contract by your electricity supplier, so it's a license to make money but with no obligation on your behalf to keep up the supply.

What happens if you move house? You can take what's left of your FIT contract with you if you wish, and you can either take or leave your panels. If I understand right you can also leave what's left of the FIT contract with the incoming householder – so it ought to be something that becomes factored in to house value.

At present, solar panels are too new for estate agents to be able to say what effect they are having or will have on house prices. My advice would be to play safe and presume zilch. The benefits, of persuading a prospective buyer that they stand to get free electricity even if you do not take your FIT with you, are likely to be offset by a wariness of anything beardy-wierdy-goaty-cheesey – unless you live somewhere like Glastonbury. Website discussions on this include comments like "Camilla's Mum" saying: "Aaah, but what happens when you try to sell a property with these seriously ugly panels? That'll be an interesting scenario." All I can say is that if I was looking to acquire or build a house these days I'd be very switched on to its aspect, roof tilt and shading. Already panels are coming out built into tiles that look like slate and panels that provide both solar and hot water, using the water to cool the panels and so raise efficiency, so lots of developments for an exciting future.

All told, and notwithstanding my suggestion for the NUB, the FIT gives an important incentive as it reduces the payback period and makes panels an attractive option even for people who might be moving house in the medium term.

[9] **Comparison with Life Assurance Returns – IRR Calculations**: Internal rate of return (IRR) is a part of discounted cash flow methodology as applied by economists in looking at investment appraisal. Its logic is: "If my investment is going to yield this future stream of cash flows, what rate of interest does that equate to averaged out across the lifetime of the investment?"

It's years since I studied the maths of it all, so for back-of-the-envelope purposes I've cheated by using an online calculator and entered my initial investment of £5,000, with a future flow of returns from the combined FIT and savings on bills at £726 a year. But only so for the first 10 years. For the remaining 10, I've dropped the returns by 20% to £581/annum to allow for efficiency fall-offs in the panels and possible inverter replacement. I've also not allowed for inflationary increases on the FITs and fuel bill savings. Even on this conservative basis of calculation, my anticipated returns whack in at an IRR of 12.66%. This is exactly what some of the financial press are claiming (on a different set of assumptions), but not as high as some of the more irresponsible sales claims out there.

In comparison, if a person with a probable life expectancy of 20 years invested £5,000 to buy a level payment annuity it would only yield, at current best rates, about £240 per annum, or an initial £130 if index linked in the way that the FIT payments are (based on this *Daily Mail* calculator). £240 is a 4.8% return and £120 is 2.6% - and so solar panels, in round figures, ought to yield between 3 and 5 times the annuity rate, and that's without tax coming into the equation which it would do with an annuity.

Bottom line: financially the benefits of panels on the roof are such a no-brainer that there's only one choice for the Government – tax them!

[10] **Returns on Investment (ROI) for Smaller Solar Systems**: Most frugal users of electricity can't long sustain the use of even half of what a 4 kW system produces in full sunshine. As such, Tobi Kellner (the Renewable Energy Consultant at the Centre for Alternative Technology (CAT) in Wales) has pointed out to me that smaller units can provide a higher rate of return because their output is more readily absorbed by a household's baseload requirement. Householders who are out during the day need to be careful in making their ROI calculations as they may get relatively little benefit from using the power they produce themselves. Large energy-guzzling homes with heated swimming pools and lights left on all day may, in contrast, give nothing back to the grid but still get paid the export tariff as if they did!

[11] **How Clean? The Embodied Energy of Solar Panels**: Embodied energy is the energy incorporated in the provision of a product or service. It used to be that solar voltaic panels had an embodied energy of about 25 years. My own web research suggested that our panels, used in their relatively inefficient west Scottish context, would probably take about 8 years to cover their embodied energy. However, when I went in May 2013 to talk with Tobi Kellner at CAT in Machynlleth, he said that my figures were out of date and he'd reckon that it's now more like four years of an embodied energy payback period in a UK context. I also asked his opinion on rare earth elements used in their manufacture. What small quantities may be used were not something he saw as a major issue. It must be remembered that other means of power generation, such as coal fired and nuclear, also carry an embodied energy and environmental pollution footprint.

Tobi added that at CAT they have recently dismantled solar panels that they've had running for many years and were pleasantly surprised to find that apart from some discolouration, they remained in pretty good nick. And as the market develops, facilities for recycling the materials in old panels are coming on stream.

[12] **Ecologically Perverse Behaviour**: To seek to raise economic efficiency without also keeping an eye on ecological (i.e. mainly carbon) efficiency can result in ecologically perverse behaviour. For example, turning on the washing machine at noon to get the benefit of one's own free power deprives the grid of power that can meaningfully displace dirty peak-demand power stations. There is therefore a tension between wider social good and what individually justifies buying panels in the first place. Ecologically, it would be better to put the washing machine on at night when the grid is down to baseload and then export one's daytime solar power to reduce the amount of polluting fuels being burnt. A great virtue of the NUB is that it would remove the incentive that drives such perverse behaviour. Mind you, it would also partly undermine my rationale for the ASHP! That adds up so well because it uses power I'd otherwise not get paid for exporting. All said, it is a part of ecological adaptation to live with things the way they are until the latitude arises for change.

[13] **Thanks to Mull & Iona**: My warm thanks to Nigel Burgess for having invited me to speak at the 2012 Mull Renewables Fair organised by Sustainable Mull and Iona. It was one of those events where I had more to learn than to teach. The exhibitor I spoke to that day was Sandy Brunton of the Argyll-based Lowergy Ltd who supply (amongst other products) the Sharp InVest 8.2 kW (output) ASHP. He told me they had installed one in the basement of Birlinn Ltd where Hugh Andrew stores his stock of books, and that Hugh had found that not only was it a cost effective means of heating, but it also improved the air quality for stock. Hugh has confirmed this, saying he is well pleased with their investment, and he is now looking at adding solar panels. The mostly positive experience of my friend Adrian who has installed one on his wall (due to space restrictions) can be read about here.

[14] **ASHP, GSHP, WSHP and Cold Weather:** Heat pumps can source their energy from the air, the ground (either through boreholes or pipes laid in trenches in the garden) or water, such as a loch, river or the sea. They can either deliver hot air, like my air-to-air source heat pump, or hot water which can be run through radiators or, most commonly, run through pipes for underfloor heating. GSHP and WSHP tend to be expensive to install. Ballpark figures that I've heard for GSHP have tended to be over £10,000 and can involve digging up the whole garden or bringing in a drilling rig. Their advantage is that ground (or water) temperatures tend to be relatively stable and this gives a reliable year-round heat pump performance.

In contrast, while the upside of ASHPs is that they are relatively cheap and easy to fit, the downside is that the COP falls off as it gets colder and I'm told, by people in the west of Scotland, that they don't do well in direct exposure to gale force winds either. As such, an ASHP can be least effective when most needed. That doesn't matter if you have an alternative heating system such as we have with both our stove and the gas. But if you're wholly dependent on ASHP, and you're not living somewhere with a mild climate like coastal west Scotland and a sheltered corner into which to locate your ASHP outdoors unit, then it may not be a suitable technology for you.

Heat pump efficiency is rated according to the COP or *coefficient of performance*. This is the ratio energy in to energy out. Our Bosch Worcester Greensource claims a COP of 4.6 meaning that for every kWh in, it can deliver 4.6 kWh out. However, that is at an optimal outside operating temperature of 7°C. It raises 2 ancillary questions. 1) What is the COP seasonally adjusted to real-life operating conditions? This is called the SCOP – the *seasonally adjusted COP* – and ours is rated at 3.8. 2) How quickly does the COP fall off in cold weather? Ours falls to 3.2 at -7°C and 2.5 at -15°C. It unit is designed to cut out completely at -20°C. As such, and bearing in mind the present 3:1 carbon intensitivity and cost ratio between gas and electricity, anything below -7°C would mean that in our situation, we'd be better shutting off "Puffer" and shifting over to the gas central heating *unless* it happened to be bright sunny winter weather, so the electricity off the solar panels was free anyway.

I find that heat pumps have a very mixed press amongst alternative energy people. Some are real enthusiasts; others full of tales of woe and not without reasons. A 2010 study by the Energy Savings Trust revealed that many heat pumps have been badly installed and therefore under-deliver. So far I have invariably found that the tales of woe fall into one of two camps. A) People who have been wholly reliant on an ASHP living in parts of the country, such as upland areas, where it has not been adequate to cope with the outside cold and unprotected exposure to gales. B) People using GSHP systems that need to be left on 24/7, usually to provide underfloor heating which cannot be controlled with quick response and therefore high electricity requirements. Without exception the people I have so far spoken to with pessimistic views have not had experience of the type of small and inexpensive ASHP that we are using or with the idea of using it in conjunction with solar panels. It is largely to publicise this approach that I have written the present article.

[15] **High versus Low Grade Energy Considerations**: An old mentor of mine on energy issues, the late Professor Malcolm Slesser of Strathclyde University and the Centre for Human Ecology, was always very keen to emphasise that electricity is a "high grade" energy and ought not to be wasted on "low grade" applications such as the heating of space and water. By "high grade" he meant that its use was eminently flexible. You can run a motor, light or tranny radio on electricity, but not directly from a lump of coal. As such, he used to say, we need to think about national energy needs not just quantitatively, in terms of watts, but also qualitatively, in terms of energy grade, and here solar panels win hands down because they produce power of the highest grade.

[16] **Thanks to Papua & New Guinea**: I have mentioned the connection with this Indonesian work in the western side of New Guinea island for two reasons. First, it is a lovely completion of a circle that began nearly three-and-a-half decades ago in Papua New Guinea where I had the opportunity to work with small scale hydro. Second, I have written this article to benefit Reforesting Scotland readers while the FITs are still good, but I am acutely aware that many will not be in a position to do what we've been able to do. I therefore wanted to set our own advantage in a wider context of it being part of what has been a long term commitment to mostly unpaid or low paid work in that part of the world. I think it's important to see that sometimes, after years of slugging our guts out on an issue, it can actually be that what goes around comes around – that we are working with things that can make our lives better in the end, and becoming attuned to them via voluntary work is not all about giving out. A short press report on our work in Papua and how it ties in with climate change and land reform in Scotland can be viewed here.

[17] **Suppliers and Costs of ASHP:** See Note 14 on performance data. I chose the Worcester Bosch Greensource air-to-air sourced heat pump because its low normal-functioning energy requirement of just 1.2 kW. That sits nicely with what my solar system is often churning out during the day. This brand was also the top recommendation in *Which?* – the consumer testing magazine – as of early 2013. From the Bosch website I got a list of local approved suppliers and ended up getting two quotes. I went with Vincent Coyle of Airdrie who came in at just under £2,000 fully fitted (5 year guarantee) and who tells me he can supply right across the Central Belt (including into Fife). I have been very impressed indeed. Although he is a gas fitter he himself has no interest in heating his home by gas, having gone over entirely to ASHP.

But watch out for regional cost differentials. A friend who lives in Henley-on-Thames got a quote for the same as I've got and he was cited £6,000 including fitting. The pump itself costs only about £1,000 wholesale, so his plumber/engineer was wanting £5,000 for half a day's fitting work! It's the same with solar panels. I note the price varies depending on labour markets around the UK, and I got all mine put in when the economy was sluggish – so that's a factor to think about too.

Vince tells me that the Greensource is no longer the only option at that league of power consumption. He said that Daikin have also started doing a small model and very competitively priced. I like the fact that Bosch are not a conventional company with shareholders, but a trust, the profits going mainly to educational causes: but it would still be worth shopping around, and if you are in a rural area your choice of makes will depend on what local suppliers have got the agencies for.

[18] **ASHPs - Noise & Planning Considerations**: Our ASHP is very quiet. It makes a gentle whooshing noise in the front garden and is completely hidden from the street behind our hedge. The indoor unit similarly makes a gentle blowing noise above the door which is why we call it Puffer. Where we live, less than half a mile from the M8 and a similar distance from the Clyde Tunnel dual carriageway, you wouldn't notice the sound from the pavement outside the house or any neighbours' garden. However, in a quite rural area your neighbours should be considered if your outdoor unit would be close to their boundary. Similarly, you wouldn't want to be fitting the outdoors unit close to a neighbour's or your own window if, say, living in a block of flats. It's all about niche.

That raises the question of planning permission. Since 2011 and under suitable conditions, ASHPs are considered to be a "permitted development" for planning purposes. However, the regulations vary in different parts of the UK. This leads to considerable confusion within the industry and on websites – not least because most websites cite the English situation and simply suggest that permissions are no longer an issue.

Since I am engaged with renewable energies not just for personal benefit but to further a personal concern on climate change I'm going to be completely straight about what I've found out as I've gone along. The English planning rules allow the positioning of an ASHP as a permitted development within a metre of a boundary provided noise limitations are met. I contacted 3 different Glasgow suppliers and, perhaps based on this, they all told me the same thing: that planning permission is not required – but they don't like fitting them where they'd cause any obvious intrusion, like on the front of buildings, or in conservation areas. I proceeded on that advice.

However, I then noticed that in the *Stornoway Gazette* to which I subscribe ASHP installations were being listed under the planning permission listings. Further investigation unveiled that the Scottish regulations are distinct, and different. See them both compared on the Energy Saving Trust website here. Whereas in England you generally don't require planning permission for a small ASHP (with an external unit less than 0.6 m^3 – ours is only 0.01 m^3 and so, insignificant) in Scotland there is no consideration given to size and as such, the presumption seems to revolve around huge clunky Stone Age AHSPs with a distance from the boundary stipulated as 100 m^3 to be considered a permitted development.

For the benefit of readers while writing this article I phoned up the Glasgow planning office. I'd already been on their website at an earlier stage and could find no trace of them ever having approved an ASHP – which added weight to what the suppliers had been telling me. It was difficult to get through because they are so short-staffed, but when I eventually managed to speak to a duty planning officer she said she didn't know what the situation but would speak to a colleague and call back. This she promptly did. She said that in Glasgow they had never actually had an application to install an AHSP and this was why their website drew a blank on the question. The regulations strictly interpreted say that if within the 100 m^3 boundary limit the planning office ought to be approached. I said, "How come all the suppliers say that's not necessary," to which she said, presumably off the record, "probably because this is Glasgow." I said, "So, this is one of those situation where nobody's going to raise an eyebrow unless somebody raises an eyebrow?" She was very helpful. She could clearly see the issue. But she played it very professionally and said that the correct procedure would be for a test application to be made on which basis the planning office of Glasgow would "take a view" on the matter.

Where does that leave things? In terms of black and white, it's very clear, and I'd suggest that to help the Scottish Government meet its climate change commitments consideration should be given to adopting something more akin to the English regulations. In grey terms, however – in terms of "this is Glasgow" or whatever – it might be a matter of letting sleeping dogs lie. All that I would say is that if the planning officers would wish to come and "take a view" retrospectively on my installation I'd be very happy indeed to cooperate with them, and would update this webpage accordingly thereafter. I'd also suggest to Reforesting Scotland readers that there may be regional variations in how strictly the planning rules are applied, and therefore take sound local advice – especially if you don't have good relations with your neighbours. Our neighbours in all directions are great – but then, as the council's officer said, "this is Glasgow"! It would seem to me that an approach that might be considered would be to apply the same principles to a small AHSP as would be applied to an air conditioning unit – they are, after all, pretty much the same thing apart from what's written on the box. To the best of my knowledge planning is only required for a domestic air condition unit if you're in a conservation area.

[19] **ASHP and Domestic Layout**: The need to leave doors open when using an AHSP is an important niche consideration. They work best in open plan contexts. In conventional houses with rooms, Bosch reckon (p. 5) that the temperature drops by 2° C for every room the air has to pass through. In chilly parts of April I found that I needed the thermostat on Puffer's remote control set at 24° to make it up the stairs, along a bit of landing and into my room with delivery at 20.5°. Some houses would simply not be suitable or would require more than one ASHP. With Puffer located above our inside front door we can direct the vanes to blow upstairs or downstairs depending on which parts of the house we're using. The vanes can also be set to oscillate.

The remote control that comes with the Bosch Greensource allows control over a 24 hour period, but not for regular programming. One has to set it each evening to come on at a particular time in the morning and switch off by itself in the evening. This is because the general assumption is that people will leave them on all night controlled by the thermostat, just turning it right down for the night. However, doesn't suit our usage. I often get up early to write so I need my office warm by 7. To leave Puffer on full blast all night is not only expensive but it overheats the rest of the house. As such, in the cold weather this year in April and early May I was setting it to come on at 5 am with most of the downstairs doors closed so it would have my space well warmed by 7.

I have spoken to Bosh about the lack of a fully controllable time clock and they say they are considering building in a more fully featured unit in future models.

[20] **Met Office Statistics:** Let me be clear on my use of Met Office statistics since their website is undergoing changes, and some of the material and the assumptions behind it can be hard to locate. Our nearest weather station to Govan is Paisley, 4 miles west. I draw my data on sunshine hours and temperature from the chart of running monthly weather stats available by clicking on the button for your nearest weather station on the map given here (normally updated around the middle of the following month). That page specifies: "The monthly mean temperature is calculated from the average of the mean daily maximum and mean daily minimum temperature i.e. (tmax+tmin)/2." As such, where the data tells me that in April 2013 tmax was 10.8°C and tmin was 3.2°C I have drawn a daily mean as 7.0°C. Sorry if that's stating the obvious, but there is so much room for get hold of wrong ends of sticks in looking at such data that it's best to be explicit on methodology. The Met Office also gives historic weather station means for 1981-2010 temperatures at Paisley, our nearest – and again I take a simple average of tmax and tmin as a proxy for the daily temperatures. As such, our local temperature figures for the 3 months since we got our AHSP installed are as follows – actual with the usual seasonal norms shown in parentheses: April 8.5 (7.0). May 11.6 (10.5). June 14.1 (15.9). The seasonal norm for March is only 6.3, thus this year's April figures were closer to a normal March. I've yet to get full figures for July, but press reports at the time this article goes to press are claiming it to have been the second warmest July on record in Scotland (after 2006), and certainly, my solar panels have made 563 units that month, which is 41% over anticipation. (That won't last!).

Outside temperatures are very important in making comparison calculations of domestic carbon footprint between years because the greater the temperature gradient between indoors and outdoors, the greater the heating needed and therefore the higher the carbon footprint. That is why, although my combined solar/ASHP system has only been running in the spring and summer thus far, the April figures were very significant because 7.45°C is the Met Office mean temperature of Scotland as a whole (source: Met Office), so what went for me in April is a good proxy for across the board in Scotland.

What I said in my article's body text about having used gas only for water heating since April was a simplification because the word count was too tight to give the caveats. In fact, there were a number of days when I did use gas central heating as part of my experiments to compare with the heat pump's performance. Also, there were 3 days in May when we had visitors staying while we were away without a chance to explain how to use Puffer, and being from overseas it was surprising how much gas they went through! My April-June figure of an 81% carbon footprint reduction would therefore have been even higher had it not been for these irregularities. As it was, April showed a carbon footprint reduction of 65%, which should have been higher, but in May it was 85% in June, a whopping carbon negative 104% reduction, and in the July figures just in, 118% reduction (i.e. exporting more energy than we use). Yes, it was a sunny spring, but also a cold spring – the media were saying "the coldest in 50 years" – so swings and roundabouts there. My day-by-day data logging is here for April, and here for May, but as from June I have gone to monthly logging which will be sustained here for at least this first year. Also there I've got lots of data sources summarised.

Two further sets of assumptions are important for those of you who rightly like to pick at the details – for those who I congratulate on still being with me in this document. One is that I think I can reasonably assume that half my solar power still gets exported to the grid. I'm saying that because when the panels are going full whack in the summer, we've hardly any power consumption and even if Puffer is on a modest dehumidify and air filter cycle, "he" only uses two or three hundred watts in so doing. I'm therefore left scratching my head as to why it is that much of the time in May/June Puffer would be nicely warming the whole house while our panels ("she") were turning out maybe 800 watts in brightish cloud, and we'd still be on export (as indicated by the green light on the Scottish Hydro meter). How come that even with the ASHP we appeared to be heating the house on so little? I think the answer may be that to run the central heating on low, as we might previously have done, was an inefficient mode in which to use gas central heating. Our boiler is supposed to be 90% efficient, but I bet that's only when running at 30 kW full pelt, and it doesn't allow for losses in the pipes coming down from the attic. As such, Puffer's direct application of heat into the heart of the house perhaps carries a hidden level of relative efficiency gain. Another reason is that temperatures between rooms using Puffer are controlled by opening/closing doors. For example, if we've got the washing machine on, we'll typically close all the doors in rooms we're not working in, but later open them to warm the house through if the sky's bright but it's cold outside. Opening and closing doors is a far easier discipline than remembering to turn down thermostatic valves on radiators when the gas central heating's on. Often, with the gas, we'd find we'd forgotten to turn a valve down, thereby heating a room not in use. As such, part of our efficiency gain is coming from different usage patterns that, in our particular situation, works well for us.

All that said, in making what I think is a fair assumption that we probably still export pretty much half of our notional 3,000 kW anticipated annual solar production back to the grid (consistent with the FIT assumptions). I have factored this in to my carbon calculations, so my spreadsheets show half of our production on average being exported back. As I've not profiled this by month, it has the effect of overstating winter carbon footprint reductions and understating summer ones (when on sunny days, most of our production is back-exported), but on balance the seasons will cancel each other out. Watch my spreadsheets, however, to see how things develop over a full year's cycle and, for that matter, over successive years.

The second assumption I've made is about monthly apportionments of our prior period gas and electricity bills and their consequent carbon footprints. I only had biannual historic data from my bills, sometimes from estimated meter readings. I've therefore smoothed the four-year data and apportioned usage in direct proportion to month by month mean temperature variations. This is shown in my spreadsheet given here and it has the effect of creating a 60 percentage point differential between warm and cold months. That may be a bit out – I am not a heating engineer, and it may be that U-values for heat flux through building materials are not always directly proportional to the temperature differential - but looking at my April daily data when the weather was cold, I suspect I'm not too far out.

[21] **Heat Pump Cost Benefit Analyses:** The ASHP is guaranteed for five years and has an expected maintenance-free lifespan of 12 – 15 years, maybe more for us because we are not using it round the clock. As such, at a £2,000 cost, its depreciation will be, say, £150 a year. The calculations get a bit complex to anticipate because of monthly variations. I'd rather wait anther year before pronouncing. But very roughly, if it can save just that £150 of capital depreciation off our previous £757 gas bill as well as paying for the electricity that it doesn't get for free off the panels, then it will have washed its face. In addition, Vérène, being from the south of France, is so much happier with what "Puffer" is providing. Before we used to often turn the central heating off during the middle of the day and heat our offices with wee 500 watt oil-filled heaters. She'd wander about with a hot water bottle. This spring there's been none of that and she's found it very much more relaxing. She also very much prefers the heat quality. Being filtered air and with ionisation (to capture smells, spores, etc) it is a very clean air that avoids the stuffiness of central heating. This was part of why we experimented with this system, since I've developed some asthma since moving to the city, possibly linked to all the motorways around us. Apparently a lot of people find ASHPs helpful for pulmonary conditions.

[22] **Solar Grid Parity under a NUB Basis with DCF Investment Appraisal Methodology – the Monbiot v. Leggett Bet**: OK … so this is the really exciting calculation but it's not for the faint hearted and it has me teetering on the edge, and possibly over

the edge, of my competence. The $64,000 question is: *Have we now reached the point where "the future is solar"?* In other words, where do we stand with respect to the holy grail of "grid parity"?

In 2010 George Monbiot challenged Jeremy Leggett with a £100 bet. Jeremy had said that by 2013 solar would have reached grid parity. George, who holds that the money spent on solar FITs would be better spent on insulation, disputed that. At midsummer in 2013 George called for "pistols at dawn" and called in his bet. Although Jeremy had not responded to the original challenge, George claimed to be the winner - albeit in the nicest way (by the end of his article).

To claim victory, however, meant defining what had been meant by "grid parity". Definitions vary, so George contacted the government's Department of Energy & Climate Change and was told: "Grid parity can be defined as the point at which Government support for a technology is no longer required." DECC added: "Grid parity for domestic scale solar power has not been reached. … The Feed-in Tariff scheme currently provides generation tariff of 15.44p per kWh, plus an export tariff of 4.64p per kWh for domestic scale installations."

George concluded: "In other words, though the subsidy has come down sharply from 2010, which partly reflects a real decline in the price of solar power and partly reflects the extraordinary generosity of the initial tariff, we're a long way from grid parity. This, I think, highlights the danger of believing what we want to believe."

But is my good friend George, who I treat as an oracle of wisdom on most issues, actually right on that one? Just because a subsidy is in place does not necessarily mean that what is being subsidised is uneconomic. The world of industry is full of such perverse subsidies, such as those the oil industry gets. Look at the subsidies going into building power stations in general.

Let me work on basis of that definition: : "Grid parity can be defined as the point at which Government support for a technology is no longer required." Much though I admire the strength of George's arguments – and his point about insulation is very important, especially to tackle social justice as well as environmental sustainability - I think his position might open to challenge. In this article I have proposed the NUB – a Net Usage Basis – to encourage solar while not causing relatively poor (or merely, north facing) homes to subsidise the relatively rich. Simply by legislating for the grid to be used as a giant battery and charging customers with home generation facilities for only their net electricity usage would create a win-win situation. It would have the virtues of, a) Providing to the grid at its lunchtime demand peak (early evening is the other peak) when spot prices for power are high; b) Laundering dirty energy clean by replacing conventional sources with clean; c) Decentralise inputs to the grid and thereby cut grid losses thanks to local provision for local use thereby increasing utility profitability; and d) other intangibles, such as reconnecting householders to our dependence on nature by knowing that the weather makes them money (I've become an obsessive weather watcher, even living in the city).

A NUB would not require any subsidies. It would just take a legislative nudge and the installation of a two-way meter. The question then is this. *Have the costs of domestic solar reached a point where the returns on a NUB basis stands to economic reason?* I want to argue that they have – just – depending, of course, on your assumptions.

Assumption 1 is that government would legislate to make utility companies carry the cost, where necessary, of introducing backward-spinning meters (or digital equivalent) as part of its expectation that they cut carbon intensitivity in line with wider climate change legislation. The industry is already embarked on a massive legislation-driven programme to replace old meters with digital ones, so this is not a suggestion outwith the norms of existing policy but would be a precondition for the NUB to work.

Assumption 2 is that government would legislate for the NUB if and once the existing FIT regime comes to closure, this meaning that households would then earn the same for the energy they export as they pay for what they import. This is the key driver in my argument. Householders currently buy electricity at around 13 pence/unit while the wholesale price is around 5 pence (£50/MWh). The criticism of this assumption is that it lets householders off the hook of having to buy from the companies. The virtue of it is precisely that it starts to shift people off grid, decentralising and cleaning up the electricity generation system while empowering voters.

These assumptions are critical to my argument. They frame it as seen from the householder's (the electorate's) point of view, and therefore, in terms of what is needed to stimulate private as distinct from corporate or governmental investment. Let me proceed on that democratising basis.

The effect of a NUB is that while there would be no more FIT – no more paperwork and bureaucracy and no more envy of the solar-haves by the solar-have-nots which is highly toxic to communitarian green thinking – householders, by finding their solar energy valued as the same as what they'd buy it for, can calculate their returns on investment very simply from the retail price of electricity and their expected annual production from their roof. Furthermore, energy inflation (or deflation) is built in. As retail prices change, so will the valuation placed on what comes off the roof. We can therefore carry out our DCF (discounted cash flow) investment appraisal without the need for complex inflationary adjustments to the calculations or pumped-up discount rates that fallaciously discount the children's future.

The question before us then becomes similar to the IRR life assurance question addressed above except that in this instance, our question is simply whether, given a market-justifiable discounting rate, domestic solar panels will ever repay their investment. If they will repay on a discounted basis, the question of long that takes is actually immaterial because discounting factors in the "time value" of money. An economically rational investment decision is simply any decision that will yield a positive NPV (net present value) using a real positive discount rate (i.e. inflation adjusted or, as in this instance, inflation proofed).

The problem with DCF is always what discount rate to use. My starting point is to observe that the returns from having one's own solar panels are tax free. This gives a huge edge on the opportunity cost of most other kinds of investment. Next, I am going to compare investment options with what most people would actually do with their money. Most ordinary householders, if not spending £5k on a 4 kW solar voltaic system like I have done (I use my own example as my benchmark) would probably put the money in the building society or similar saving scheme. As such, the discount rate becomes more obvious to determine. It needs simply be the rate of return that an investor would get from the building society on a simple interest non-compounding basis (i.e. living off the revenue) minus tax, minus the rate of inflation, plus a risk premium.

At the time of writing, the best building society deals are 4%. Knock off the rate of inflation, which is running at nearly 4%, and – ouch – we can forget about the tax, can't we – except not really, because tax is still applied and what that means is a real positive discount rate of -1% for the standard punter. In other words, saving your money at present causes it to lose value, and this is likely to remain the same for the next several years under current UK economic policy.

But let's play conservative. Let's forget about tax – presume the punter is below the threshold. Let's just say that the building society currently pays you 0% interest in real positive terms (i.e. after inflation) but you expect a 3% risk premium for your solar panels and that they will have no residual value left at the end of the financial window. With that assumption, let's plug the figures into either the standard DCF formula or for greater ease, an online calculator. We're going to give it a discount rate of 2% and a stream cash flows of – in my instance – 3,000 units/annum @ 13 pence per unit = £390 worth of electricity per annum and an initial capital outlay of £5,000. How many years must I tot up my £390 worth until I reach an NPV of zero (i.e. equal to the original investment)?

Well, this online calculator I've found is really handy, because it also shows you simple payback period. Note that as you add up your £390s, you reach simple payback parity between years 12 and 13, but to accommodate the discounted cash flows, you have to push on until year 15 (including year 0) when the profitability index moves from negative to unity. And notice how I've cheated! The table only lets you go up to 15 years, which is why I jigged my risk premium at 3%! My gut instinct would have been 5% and that – at a guess – would have pushed the required stream of returns into the low 20 year mark, which is just short of the expected life of the panels – and yes, they decline in efficiency over time, but allow me that I'm basing my figures on Sunny Govan where we get a quarter less sunlight than more favoured parts of the UK.

Overall then, I would argue that under a NUB regime we're sitting on the grid parity threshold. It's so close, let's call it a straight draw between George Monbiot and Jeremy Leggett. Let neither shoot each other at dawn in a circular firing squad. Let them both buy me a nip of malt!

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Join Reforesting Scotland

Our aims:

- **Promote sustainable forest culture and economy in a well-forested land**
- **Develop the use of locally produced forest goods and services**
- **Encourage social and ecological restoration in forests and in wider land use**
- **Raise awareness of the benefits of low-energy living based on woodland resources**
- **Place the Scottish forestry situation in an international context**

About us

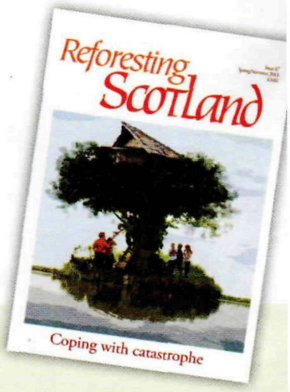
Reforesting Scotland is a networking organisation of those active in the ecological and social regeneration of Scotland. Our aims, to the left, are increasingly shared and supported, and our vision for a sustainable future is starting to become reality. There is a growing realisation of the economic and environmental values of native and community woodlands, and the social benefits of a reforested land.

We need your help and support to continue our vital campaigning work. Joining as a member has a number of benefits:

- Receive our Journal and members' newsletter, *Radical Rowan*, both published twice a year
- Join a lively virtual community – our online discussion forum and Facebook group
- Get involved in any of our projects and campaigns, or start your own
- Be part of a network of people interested in Scotland's forests and woodlands
- Meet others at talks and workshops, and our vibrant annual Gathering.

About the Journal

The publication of an informative journal is central to the work of Reforesting Scotland. It is published twice a year, in spring and autumn, and each issue carries a range of articles dealing with a specific theme, as well as regular columns. We welcome contributions – articles, drawings and photos – which may be of interest to our readers.



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