Breaking the deadlock: Iran's nuclear programme in context

Keith Barnham suggests renewable energy technologies can play a key role in arresting the spread of nuclear weapons in the Middle East and elsewhere.

The disastrous consequences of possible military intervention in Iran were described in a recent SGR-authored article.[1] President Obama will be keen to prevent any precipitate action by Israel in the run-up to November's presidential election. I suggested a new initiative to break the deadlock in a letter that the London Guardian published (in an abridged form) on 15-3-12:

> *"Your leader ("Straining at the leash", 6-3-12) urges the US to create "incentives for Iran to change course on enriching uranium". Here is a suggestion. In return for stopping all enrichment activity, the US offers to build a solar cell factory and a wind turbine factory in Iran, each capable of manufacturing systems producing one GW of electrical power a year. This would cost less than a new nuclear reactor. Within 10 years Iran could have around 15 GW of new electricity capacity, much more than its nuclear programme will produce in that time. Such distributed electricity generation is also more secure against disruption by earthquakes and hostile neighbours."*

This article will discuss the background to this proposal, weaknesses in the Nuclear Non-Proliferation Treaty (NPT) and ways renewable technology could help economic and political progress in the developing world.

Nuclear and renewable energy costs

The cost of solar photovoltaic (PV) power has fallen sharply as factories manufacturing over 1 gigawatt (GW) per year have come on stream, mostly in China.[2]

The *Kombikraftwerk* project has used real-time output of renewable generators to show that 78% of the German electricity demand can be supplied by PV and wind power with back-up from biogas.[3] With colleagues I have recently shown that peak electricity prices on the German and Italian grids are falling as the PV contribution has risen and the German grid is coping with wind and PV contributions above 30%.[4] We conclude that the fastest and cheapest route to a low carbon electricity supply would be a moratorium on all new electricity generators other than the renewables.

Renewable electricity is particularly appropriate for Iran:

1) In much of Iran 1 MW of PV will produce twice the energy (MWh) as the same 1 MW system in much of Germany.[5]
2) The wind resource in Iran is comparable to that in Germany,[6] which has already installed 29 GW of wind power.[7]
3) Wind and PV can supply those regions of Iran not connected to the national grid.
4) The renewables require no fuel and so provide more security of electricity supply than nuclear power.

The costs of my proposal are presented in Box 1. In short, construction costs for a second nuclear power station are around $6.4 billion, whereas my estimate for wind turbine plus PV factories is around $2.7 billion.[8] Iran may go for a cheaper model from Russia or South Korea for its second reactor. However, much of the increased cost in my estimate is due to post-Fukushima safety enhancements. Given Iran's earthquake history, it would be unwise to economise on safety.

The capacities that could be installed in the next ten years for each of the two options are compared in Box 2. With 15 GW of renewable power, the renewables option is far superior to the 1.8 GW of nuclear power.

The experience of Germany has been that it is the power (GW) that matters rather than energy (GWh) in

Box 1 – Cost comparison of nuclear and renewables

Nuclear

The latest figure for the 1.6 GW European Power Reactor is around £7bn.[9] Iran's second reactor is expected to be 0.915 GW (see Box 2) which @ 1.6 $/£ gives

New reactor construction cost = $6.4bn.

Renewables – technology costs

Wind: The construction cost of onshore wind power is (2.1 – 2.7) $/W and falling.[10]

Photovoltaics: The average retail price a solar cell module has fallen from 4.5 $/W in January 2009 to 2.29 $/W in March 2012.[11] However, the retail market has yet to see the full benefit of the fall. The average spot price of a PV module was 0.745 $/W on 4-7-2012.[12]

Renewables – factory costs

Commercial sensitivities mean factory costs are not always easy to find.

Wind Turbine Factory: I obtained an informal estimate from an investment analyst of $100 million for a factory producing 1 GW of wind turbines per year. This is consistent with my estimate of $130m based on figures from a newspaper report[13] of the turbine plant (excluding port infrastructure) that Siemens is building in Hull. (Siemens has not responded to my requests for information on plant capacity. However, it must be at least 1 GW/y to make an impact on the UK Crown Estate's 25 GW target for the North Sea in 2020.[14]) I took the lower estimate as Iran will probably want smaller turbines than the large offshore units planned by Siemens.

Cost of a wind turbine factory producing 1 GW/y = $0.1bn.

Solar Cell Factory: A $1.3bn investment has been made for new PV plants totalling 0.5 GW/y in Japan.[15] $2.6bn for a 1 GW/y plant is consistent with the rule of thumb from the investment analyst mentioned above that the capital cost of a PV plant should be recouped in the first two years of operation. This means $2.0bn for the capital cost assuming the spot price of PV modules is 1 $/W.

Cost of a factory producing 1 GW/y of thin-film PV modules = $2.6bn.

Renewables – installation and balance of system costs

Wind: The turbine cost is a small part of the construction costs presented above. Installation and civil engineering costs dominate. Hence an Iranian purchaser is not going to see much advantage from the donation of the factory unless some installation subsidy is agreed as part of the deal with the US.

Photovoltaics: Balance of systems costs of PV (installation, area related costs, grid connection) are generally approximately equal to the $/W module costs. One assumes these will be paid by the purchaser. The cell cost to the purchaser will be lower because the factory will not have to recoup the capital cost. A smaller subsidy than for wind could be agreed as part of the deal with the US.

meeting demand (which is also measured in GW).[4] The peak price of electricity in Germany has fallen significantly thanks a typical peak PV contribution of 28% of the grid supply in terms of power, but only 3% in terms of energy. Energy comparisons ignore the time variation of PV. PV power peaks close to the time of peak demand.[4,19]

However, even if one compares energy yields, the renewable option is still significantly better. Assuming 70% capacity factor for nuclear, 30% for wind and 20% for PV:

Energy generated in 10th year, (wind + solar PV) : nuclear = 3 : 1

Weaknesses in the Non-Proliferation Regime

This suggestion for Iran highlights a problem with the NPT first noted by the late Joseph Rotblat.[20] As part of the incentive for non-nuclear weapon states to sign the NPT, Article IV states "Parties to the Treaty.....shall also cooperate in..... the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear weapon states Party to the Treaty..." Rotblat proposed the words "nuclear energy" should be replaced by "the most appropriate form of energy". He was also concerned that the IAEA pursues Article IV activities more vigorously than overseeing safeguards. This is still the case. In 2010 only 38% of the IAEA's budget was spent on safeguards verification.[21]

Iran is a prime example of an NPT signatory state whose nuclear programme has developed according to Article IV. That was with support from Russia, but France has helped the Iranian uranium enrichment programme.[22] The 2015 NPT review conference should finally accept the wisdom of Rotblat's argument. International assistance for the development of renewable energy sources could also be expanded through mechanisms set up, for example, under the UN Framework Convention on Climate Change.

An important difference from the nuclear case is that exports to developing countries should be of wind and PV *factories*. This makes particular sense for donor states at the present time. The rise of the large PV factories in China has led to smaller PV production lines being mothballed or closed around the world.

Wind turbine and solar panel factories are much simpler to replicate than a nuclear reactor. If developing countries replicate the first factories, they can expand renewable electricity generation at an even faster rate. Ideally, replica factories should be wind and PV powered.

I can report some encouraging news. After discussing PV at a recent conference in a developing country, I was invited to their renewable energy ministry. There I was informed, in confidence, that discussions with a certain country on the supply of a PV factory were already underway.

Political and economic advantages of renewable technology in the developing world

Could PV and wind power become a force for political and economic advance in the developing world?

One of the first schemes to be implemented, the DESERTEC project,[23] plans to cover large areas of the North African desert with PV and solar thermal plants and bring the power to Europe by high-voltage direct current transmission. I do not like criticising any solar project that has managed the difficult task of raising significant funding, but I am concerned about some aspects of this scheme:

1. Clearly, improved national and international grid connections would mean the renewables could be better exploited. A good example is Italy where most of the hydropower storage is in the Alps in the far north and the best PV resource is in the south. As I have pointed out elsewhere, thanks to PV, the cost of electricity on the southern Italy grid fell to zero in the early afternoon of 2-5-2012.[4] However, governments that are anti- renewables have used the need for grid upgrades and storage and even the promise of PV electricity from DESERTEC, as reasons to cut domestic PV incentives.
2. One of the fastest growing contributions to electricity demand, particularly in southern Europe, is the use of air conditioners in domestic and office buildings. DESERTEC will bring electricity generated by the sun 2000 km or so to satisfy a rising demand caused by the sun beating down on the roofs of the buildings creating the demand! The money could be better used to build PV factories in North Africa and for developing 'Smart Windows' which generate electricity as well as *reducing* air conditioning demand.[19] I described the latter at the SGR AGM in 2005. Sadly, it has been very difficult to obtain funding for this technology. Smart windows reduce air conditioning demand by preventing direct sunlight from entering the building. Instead, it is diverted onto QuantaSol's 40% efficient solar cells.[24] The cells generate electricity that can power the air conditioning when it is needed and where it is needed.
3. Politically, how will the local population, which has seen the oil resources in neighbouring countries exploited by and for Europeans, view DESERTEC covering their land with devices to exploit their solar resource? Better to fund the factories that provide the wind turbines and solar panels that can power off-grid villages, irrigate the desert and power self-sustaining greenhouses. The latter can extract moisture from the desert air to enable the crops inside to grow on a self-sustaining water cycle.[25]

Given that wind and PV costs are falling well below the rising nuclear cost (Box 1), the motivations of any sunny, oil-rich state that opts for a nuclear programme deserves close scrutiny. Abu Dhabi has recently signed an agreement with a South Korean company for four nuclear stations; the first in the

Box 2 – Build time and power capacity comparison for nuclear and renewables

The Hull turbine factory is expected to take 2 years to build.[13] Iran has experience of manufacturing turbines on license.[16] First Solar's 1 GW/y thin-film factory in Malaysia took 2.5 years to build.[17]

Assume 2.5 years for each factory, so 7.5 years of active production each at 1 GW/y

Total wind and PV power installed after 10 years = 15 GW

The International Atomic Energy Agency (IAEA) says Iran is planning three more reactors totalling 2.16 GW to start in 2012, 2013 and 2015.[18] All three are of a different type to the existing Russian-built Bushehr-1 (capacity of 0.915 GW) which took 37 years to build.[1] The Iranians could have another 0.915 GW reactor operational by 2022, though a supplier has yet to be named.[18]

Total nuclear power likely after 10 years = 1.8 GW

United Arab Emirates.[26] Saudi Arabia has announced a 16-reactor programme, with the Chinese as possible suppliers.[27] In the latter case the weapons option has been admitted. A member of the Saudi royal family has let slip that that the kingdom might consider developing nuclear weapons, given that Israel has them and Iran may be developing them.[28]

I suggest that such countries could spend their massive oil revenues on supporting R&D on the solar applications suggested as alternatives to DESERTEC. Also they should join with existing groups researching how PV and wind can efficiently generate solar fuels such as hydrogen (from water) and methanol (from atmospheric CO_2).[29] Solar fuels produce a lot less carbon than biofuels and do not compete with food crops. They must, sooner rather than later, start replacing these states' depleting oil resources. I am not a chemist and cannot guess which of the many approaches to solar fuel generation will win. However, the fact that we now have 'triple-junction' PV cells being manufactured with a sunlight-to-electricity efficiency greater than 40%[24] must boost the practicability of solar fuel generation based on PV.

The ambiguity surrounding Saudi Arabia's nuclear programme suggests they may be losing confidence in the NPT regime. This is not unexpected, given the recent report in *Der Spiegel* that Germany is supplying Israel with submarines that can carry nuclear missiles.[30] The first three submarines were constructed in the UK, though it is not clear if these are also nuclear compatible. By signing Article I of the NPT, Germany and the UK have both agreed not to transfer "control over such weapons.....directly or indirectly" to "any recipient whatsoever". Whatever sophistry the German and UK governments use to argue that the submarines do not give Israel "control" over their nuclear weapons is beside the point. What matters is that Iran and Saudi Arabia are aware that the countries pressing them to adhere to the NPT are violating the spirit, if not the letter, of the treaty in enhancing Israel's nuclear capability. These are the weapons that are leading Iran and Saudi Arabia to consider the nuclear option themselves.

Can renewable power help solve the Israeli-Palestine conflict that is at the root of this particular nuclear instability? Hopefully, the peace process will be revived should Obama be re-elected. The US could offer to provide wind and PV factories as part of the peace deal. These would fuel economic development in Israel, Gaza and the West Bank. The latter two would no longer be dependent on Israel for their electricity. Furthermore, this dispute is fundamentally about the ownership of land. But who owns the wind and sunlight above the ground? Solutions to disagreements over the most problematic of the disputed areas could be facilitated by internationally supported agreements that the wind and PV from these regions could supply electricity (and water) to both Israel and Palestine.

The message for our political leaders is that German experience has shown that the renewables can supply all our electricity needs. Furthermore, renewables are now the cheapest, quickest to install and lowest carbon options. Donor countries seeking political and economic influence in developing countries need to realise that renewables are far more useful than nuclear to a developing country, and far safer technologies.

Keith Barnham is Emeritus Professor of Physics at Imperial College London. He was co-founder of the solar PV company, QuantaSol.

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