NUCLEAR MONITOR

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Editorial

Dear readers of the WISE/NIRS Nuclear Monitor,

This issue of the Monitor is a feature on the topic of nuclear power and climate change. We report on the launch of a new campaign − *Don't Nuke the Climate!* − and dissect and debunk the nuclear industry's claim that nuclear power is necessary for climate change abatement.

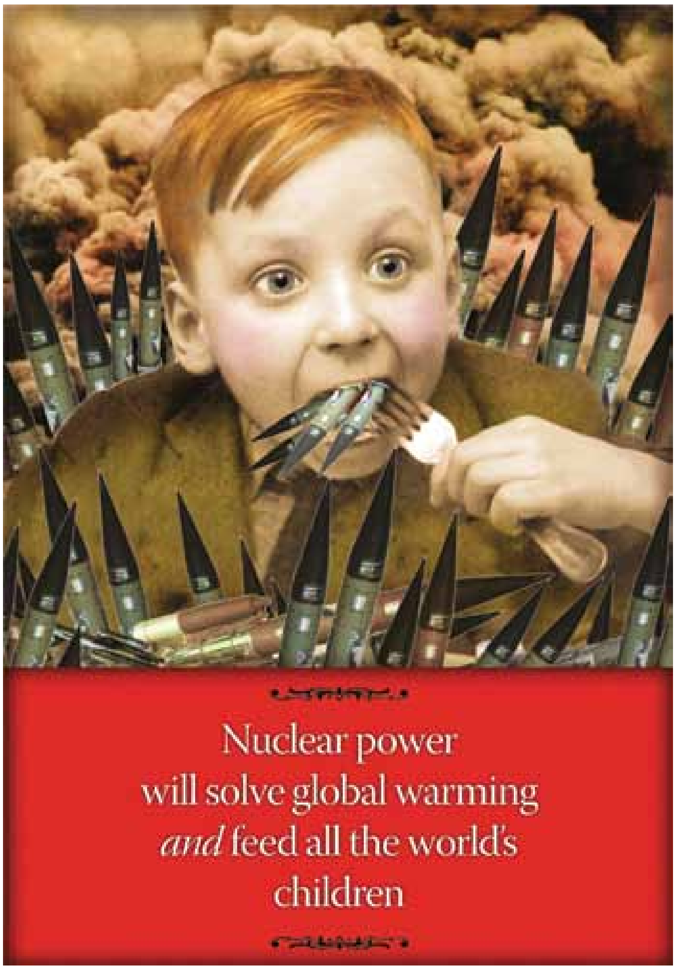
Feel free to contact us if you have feedback on this issue of the Monitor, or if there are topics you would like to see covered in future issues.

Regards from the editorial team.

Email: monitor@wiseinternational.org

Monitored this issue:

Don't Nuke the Climate! Launch of a new campaign



On June 16, seven international clean energy organizations launched a major new campaign aimed at keeping nuclear power out of all negotiations at the upcoming UN climate talks in Paris. The UN Climate Change Conference ('COP-21') will be held in Paris from November 30 to December 11.

The seven initiating groups are the two organisations behind the *Nuclear Monitor* − the World Information Service on Energy (WISE-Amsterdam) and the Nuclear Information & Resource Service (NIRS) − along with Sortir du Nucleaire (France), Ecodefense (Russia), Global 2000 (Austria), Women in Europe for a Common Future (WECF), and Burgerinitiative Umweltschutz (Germany).

Some of the same groups were critical to a similar effort at the UN negotiations in The Hague in 2000, which succeeded in barring nuclear power from the Kyoto Protocol's Clean Development Mechanism. And some of the groups also organized the large Nuclear-Free, Carbon-Free contingent to last year's People's Climate March in New York City.

Peer de Rijk of WISE-Amsterdam said: "We are calling on 1,000 civil society organisations to join us for a campaign to block the nuclear industry's lobby activities at COP-21 and instead ensure the world chooses clean energy."

Sign the petition!

The first step of this new international campaign is a petition that will be presented to world leaders in December.

Organizations can sign the petition at: www.wiseinternational.org/campaign/sign-petition

Individuals can sign the petition at: http://tinyurl.com/nonukes-cop21

The text of the petition is available in English French, Spanish, and German.

Join us in Paris.

On December 12, groups will organize an anti-nuclear block in the Global Climate March. Buses and trains will bring people to Paris.
www.wiseinternational.org/campaign/march-paris

Danyel Dubreuil from Sortir du Nucléaire said: “The government keeps extending the lifetime of aging reactors and supporting a dirty, expensive, dangerous and declining nuclear industry and will most probably use the COP-21 to try saving its national nuclear industry while promoting it as clean and climate-friendly. We condemn the sponsoring of the COP by polluting companies − and especially by EDF − and will denounce the greenwashing of the nuclear industry in Paris.”

International day of actions against nukes.

On October 10−11 an international day of action against false solutions will take place in as many countries as possible.
www.wiseinternational.org/international-day-actions-against-nukes

Sascha Gabizon from the global women’s network WECF said: “Nuclear power manifests a wide range of human rights violations, from the universal human rights to life and health, to disproportionate impacts on indigenous peoples, women, children, and future generations.”

Vladimir Sliviak of Moscow-based Ecodefense said: “Russia has had a catastrophic experience with nuclear power and nuclear waste management. At the same time, the Russian government is increasing its efforts to sell new reactors across the world as safe and climate friendly. This is cynical and irresponsible and must be stopped. There must be a clear statement made in Paris: no nukes; yes to clean energy.”

Join the virtual march.

You can buy a banner (for as little as 5 euros) which will appear on the campaign homepage (www.wiseinternational.org/campaign). Your donation will be used to finance the *Don’t Nuke the Climate* campaign. The best banner messages will be printed on real banners and taken to the march in Paris.

Websites.

NIRS has set up a new ‘Don’t Nuke the Climate’ website for US organizing and actions: www.nirs.org/cop21/dontnuketheclimate.htm

The international campaign website is: www.wiseinternational.org/campaign

NUCLEAR POWER: NO SOLUTION TO CLIMATE CHANGE

SUMMARY

1. Nuclear Power is Not a Silver Bullet

Nuclear power could at most make a modest contribution to climate change abatement. The main limitation is that it is used almost exclusively for electricity generation, which accounts for less than 25% of global greenhouse emissions. Even tripling nuclear power generation would reduce emissions by less than 10% − and then only if the assumption is that it displaces coal.

2. Greenhouse Emissions from the Nuclear Fuel Cycle

Claims that nuclear power is ‘greenhouse free’ are false. Nuclear power is more greenhouse intensive than most renewable energy sources and energy efficiency measures. Life-cycle greenhouse emissions from nuclear power will increase as relatively high-grade uranium ores are mined out.

3. Nuclear Power – A Slow Response to an Urgent Problem

The nuclear industry does not have the capacity to rapidly expand production as a result of 20 years of stagnation. Limitations include bottlenecks in the reactor manufacturing sector, dwindling and ageing workforces, and the considerable time it takes to build a reactor and to pay back the energy debt from construction.

4. Nuclear Power and Climate Change

Countries and regions with a high reliance on nuclear power also tend to have high greenhouse gas emissions.

Some countries are planning to replace fossil fuel-fired power plants with nuclear power in order to increase fossil fuel exports − in such cases any potential climate change mitigation benefits of nuclear power are lost.

5. Climate Change and Nuclear Hazards

Nuclear power plants are vulnerable to threats which are being exacerbated by climate change. These include dwindling and warming water sources, sea-level rise, storm damage, drought, and jelly-fish swarms.

'Water wars' − in particular, disputes over the allocation of increasingly scarce water resources between power generation and agriculture − are becoming increasingly common and are being exacerbated by climate change

6. Weapons Proliferation and Nuclear Winter

Civil nuclear programs have provided cover for numerous covert weapons programs and an expansion of nuclear power would exacerbate the problem.

Nuclear warfare − even a limited nuclear war involving a tiny fraction of the global arsenal − has the potential to cause catastrophic climate change.

7. Renewables and Energy Efficiency

Global renewable power capacity more than doubled from 2004 to 2014 (and non-hydro renewables grew 8-fold). Over that decade, and the one before it, nuclear power flatlined.

Global renewable capacity (including hydro) is 4.6 times greater than nuclear capacity, and renewable electricity generation more than doubles nuclear generation. A growing body of research demonstrates the potential for renewables to largely supplant fossil fuels for power supply globally.

Energy efficiency and renewables are the Twin Pillars of a clean energy future. A University of Cambridge study concluded that 73% of global energy use could be saved by energy efficiency and conservation measures − making it far easier to achieve a low-carbon, non-nuclear future.

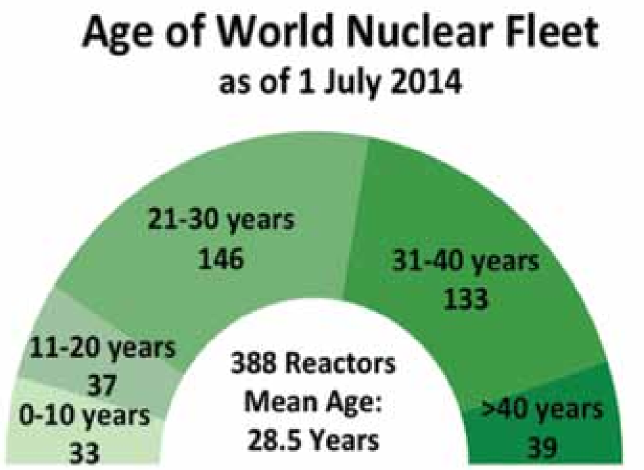
1. NUCLEAR POWER IS NOT A SILVER BULLET

"Saying that nuclear power can solve global warming by itself is way over the top".

- Senior International Atomic Energy Agency energy analyst Alan McDonald, 2004.[1]

Nuclear power could at most make a modest contribution to climate change abatement. The main limitation is that it is used almost exclusively for electricity generation, which accounts for less than 25% of global (anthropogenic) greenhouse emissions.[2]

Doubling current nuclear capacity would reduce emissions by roughly 6% if nuclear displaced coal[3] − or not at all if nuclear displaced renewables and energy efficiency. Doubling nuclear power generation would require building 437 reactors to add to the 437 existing 'operable' reactors (380 gigawatts). It would also require new reactors to replace shut-down reactors − the International Energy Agency anticipates almost 200 shut downs by 2040.[4]



Source: World Nuclear Industry Status Report, April 2015.

A 2007 report by the International Panel on Fissile Materials (IPFM) states that if nuclear power grew approximately three-fold to about 1000 GWe in 2050, the increase in global greenhouse emissions projected in business-as-usual scenarios could be reduced by about 10−20% − assuming that nuclear displaced coal.[5] The IPFM scenario (which it does not advocate) assumes a business-as-usual doubling of greenhouse emissions by 2050, with 700 additional reactors reducing emissions from 14 billion metric tons to 13 billion metric tons. Thus the *increase* in emissions would be reduced by 1/7 or 14% and *overall* emissions would be reduced by 1/14 or 7% − assuming that nuclear displaces coal.

According to a 2007 article in *Progress in Nuclear Energy*, a ten-fold increase in nuclear capacity by the end of the century would reduce greenhouse emissions by 15% percent.[6]

Clearly, nuclear power is not a 'silver bullet'.

2. GREENHOUSE EMISSIONS FROM THE NUCLEAR FUEL CYCLE

Claims that nuclear power is 'greenhouse free' are false. Nuclear power is more greenhouse intensive than most renewable energy sources and energy efficiency measures. Life-cycle greenhouse emissions from

1. Quoted in Geoffrey Lean, 27 June 2004, Nuclear power 'can't stop climate change', The Independent, www.independent.co.uk/environment/nuclear-power-cant-stop-climate-change-44804.html
2. Electricity plus heat account for 25% of emissions. IPCC, 2014: Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the IPCC, p.9, www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf
3. The basis for the calculation is as follows: Ian Hore-Lacey from the World Nuclear Association claims that doubling nuclear power would reduce greenhouse emissions from the power sector by 25%, and the power sector accounts for less than 25% of total emissions. Ian Hore-Lacy, 4 May 2006, 'Nuclear wagon gathers steam', *Courier Mail*.
4. International Energy Agency, 2014, 'World Economic Outlook 2014', www.worldenergyoutlook.org
5. International Panel on Fissile Materials, 2007, 'Global Fissile Material Report 2007', Chapter 7, http://fissilematerials.org/library/gfmr07.pdf
6. Tae Joon Lee, Kyung Hee Lee, and Keun-Bae Oh, 'Strategic Environments for Nuclear Energy Innovation in the Next Half Century', *Progress in Nuclear Energy*, Vol. 49 (2007), p.399 (pp.397−408), www.sciencedirect.com/science/article/pii/S0149197007000467. Cited in Moeed Yusuf, Nov 2008, 'Does Nuclear Energy Have a Future', Boston University, fn.54, www.bu.edu/pardee/files/documents/Pardee-Nuclear-Yusuf.pdf

nuclear power will increase as relatively high-grade uranium ores are mined out and give way to the mining of lower-grade ores.

Greenhouse emissions arise across the nuclear fuel cycle – uranium mining, milling, conversion, and enrichment; reactor construction, refurbishment and decommissioning; waste management (e.g. reprocessing, and/or encasement in glass or cement); and transportation of uranium, spent fuel, etc.

Academic Benjamin Sovacool wrote in a 2008 paper:

"To provide just a rough estimate of how much equivalent carbon dioxide nuclear plants emit over the course of their lifecycle, a 1,000 MW reactor operating at a 90 percent capacity factor will emit the equivalent of 1,427 tons of carbon dioxide every day, or 522,323 metric tons of carbon dioxide every year. Nuclear facilities were responsible for emitting the equivalent of some 183 million metric tons of carbon dioxide in 2005. Assuming a carbon tax of $24 per ton − nothing too extreme − and that 1,000 MW nuclear plant would have to pay almost $12.6 million per year for its carbon-equivalent emissions. For the global nuclear power industry, this equates to approximately $4.4 billion in carbon taxes per year."[7]

In a ground-breaking study Sovacool screened 103 lifecycle studies of greenhouse emissions from the nuclear fuel cycle to identify the most current, original, and transparent studies.[8] He found that the mean value from those studies was 66 grams of carbon dioxide equivalent per kilowatt-hour (gCO2e/kWh).

Sovacool's paper provides the following figures (gCO2e/kWh):

Wind	9−10
Hydro	10−13
Biogas	11
Solar thermal	13
Biomass	14−31
Solar PV	32
Biomass	35−41
Geothermal	38
Nuclear	66
Natural gas	443
Diesel	778
Heavy oil	778
Coal	960−1050

Sovacool states:

"Offshore wind power has less than one-seventh the carbon equivalent emissions of nuclear plants; large-scale hydropower, onshore wind, and biogas, about one-sixth the emissions; small-scale hydroelectric and solar thermal one-fifth. This makes these renewable energy technologies seven-, six-, and five-times more effective on a per kWh basis at fighting climate change. Policymakers would be wise to embrace these more environmentally friendly technologies if they are serious about producing electricity and mitigating climate change."[9]

In a 2009 paper prepared for the Australian Uranium Association, academic Manfred Lenzen concluded that life-cycle greenhouse emissions for nuclear power range from 10−130 gCO2e/kWh with the main variables being ore grades, enrichment technology, reactor fuel re-load frequency and burn-up, and to a lesser extent enrichment level, plant lifetime, load factors, and enrichment tails assay. Lenzen calculates a "worst case" – 0.01% ore grade, 75% load factor, 25 year lifetime, only diffusion enrichment, and a carbon-intensive background economy – resulting in emissions of 248 gCO2e/kWh.[10]

Others calculate still higher values, for example by assuming energy- and emissions-intensive burial of large volumes of low-level ore, waste rock, and mill tailings, rather than the current practice of surface storage.

Life-cycle greenhouse emissions from nuclear power will increase as relatively high-grade uranium ores are mined out. In 2009, mining consultancy firm CRU Group calculated that the average grade of uranium projects at the feasibility study stage around the world was 35% lower than the grades of operating mines, and that exploration projects had average grades 60% below existing operations.[11]

The extent of the increase in the greenhouse intensity of uranium mining is the subject of debate and considerable uncertainty. It depends not only on declining ore grades but also on other variables such as the choice of tailings management options at uranium mines.

Writing in the *Journal of Industrial Ecology* in 2012, Warner and Heath stated that emissions from the nuclear fuel cycle could increase by 55−220% with declining uranium ore grades.[12]

Academic Dr Mark Diesendorf states: "In the case where high-grade uranium ore is used, CO2 emissions from the nuclear fuel cycle are much less than those of an equivalent gas-fired power station. But the world's reserves of high-grade uranium are very limited and may only last a few decades. The vast majority of the

7. Benjamin Sovacool, 2008, 'Nuclear power: False climate change prophet?', http://scitizen.com/future-energies/nuclear-power-false-climate-change-prophet-_a-14-2136.html
8. Benjamin K. Sovacool, Aug 2008, 'Valuing the Greenhouse Gas Emissions from Nuclear Power: A Critical Survey', *Energy Policy* 36 (8), pp.2940-2953, www.sciencedirect.com/science/article/pii/S0301421508001997 www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf
9. Benjamin K. Sovacool, 11 Dec 2009, 'Nuclear Energy and Renewable Power: Which is the Best Climate Change Mitigation Option', Nuclear Monitor #699, www.wiseinternational.org/sites/default/files/images/NM699.pdf
10. Manfred Lenzen, 2009, 'Current state of development of electricity-generating technologies – a literature review', http://web.archive.org/web/20140124203606/http://aua.org.au/Content/Lenzenreport.aspx
11. CRU Group, 2009, 'Next generation uranium – at what cost?', http://web.archive.org/web/20101121115919/http://crugroup.com/Documents/UraniumPressRelease2009Sep23.pdf
12. Ethan S. Warner and Garvin A. Heath, April 2012, 'Life Cycle Greenhouse Gas Emissions of Nuclear Electricity Generation: Systematic Review and Harmonization', *Journal of Industrial Ecology*, Vol. 16, Issue Supplement s1, pp.S73–S92, http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2012.00472.x/full

world's uranium is low-grade. CO2 emissions from mining, milling and enrichment of low-grade uranium are substantial, and so total CO2 emissions from the nuclear fuel cycle become greater than or equal to those of a gas-fired power station."[13]

Keith Barnham, Emeritus Professor of Physics at Imperial College London, states that for ore with uranium concentration around 0.01%, the carbon footprint of nuclear electricity could be as high as that of electricity generation from natural gas.[14]

The German Environment Ministry stated in a 2006 report that a modern gas-fired power station in connection with heat production (co-generation) could be less carbon intensive than nuclear power.[15]

Some nuclear lobbyists claim that Generation IV fast neutron reactors would reduce emissions from the nuclear fuel cycle by using waste products (esp. depleted uranium and spent fuel) as fuel instead of mined uranium. One of the problems with that arguments is that Generation IV reactors are − and always have been − decades away:

- The Generation IV International Forum states: "Depending on their respective degree of technical maturity, the first Generation IV systems are expected to be deployed commercially around 2030−2040."[16]
- The International Atomic Energy Agency states: "Experts expect that the first Generation IV fast reactor demonstration plants and prototypes will be in operation by 2030 to 2040."[17]
- A 2015 report by the French government's Institute for Radiological Protection and Nuclear Safety states: "There is still much R&D to be done to develop the Generation IV nuclear reactors, as well as for the fuel cycle and the associated waste management which depends on the system chosen."[18]
- The World Nuclear Association noted in 2009 that "progress is seen as slow, and several potential designs have been undergoing evaluation on paper for many years."[19]

As for the real-world experience with fast neutron reactors, for the most part they have failed every test including carbon intensity. White elephants such as Japan's Monju reactor and France's Superphenix produced so little electricity that the carbon intensity must have been high. Monju operated for 205 days after it was connected to the grid in August 1995, and a further 45 days in 2010; apart from that it has been shut-down because of a sodium leak and fire in 1996, and a 2010 accident when a 3.3 tonne refuelling machine fell into the reactor vessel.[20] The lifetime load factor of the French Superphenix fast reactor − the ratio of electricity generated compared to the amount that would have been generated if operated continually at full capacity − was just 7% percent, making it one of the worst-performing reactors in history.[21]

3. NUCLEAR POWER – A SLOW RESPONSE TO AN URGENT PROBLEM

Expanding nuclear power is impractical as a short-term response to the need to urgently reduce greenhouse emissions. The industry does not have the capacity to rapidly expand production as a result of 20 years of stagnation. Limitations include bottlenecks in the reactor manufacturing sector, dwindling and ageing workforces, and the considerable time it takes to build a reactor and to pay back the energy debt from construction.

One constraint is the considerable time it takes to build reactors. The World Nuclear Industry Status Report 2014 noted that the average construction time of the last 37 reactors that started up was 10 years; and that at least 49 of the 67 reactors listed as under construction have encountered construction delays.[22]

The development of new reactor types − even those which are just modified versions of conventional reactor technology − further delays the construction and deployment of nuclear power. For example the EPR in Finland is 7−9 years behind schedule, and the EPR in France is five years behind schedule (and counting).[23]

Nuclear power is still slower for countries building their first reactor. The IAEA sets out a phased 'milestone' approach to establishing nuclear power in new countries, lasting from 11−20 years: a pre-project phase 1 (1−3 years), a project decision-making phase (3−7 years) and a construction phase (7−10 years).[24]

The French Nuclear Safety Authority (ASN) says that the initial development of a nuclear power industry requires at least 10−15 years in order to build up skills in safety and control and to develop a regulatory framework − that's 10−15 years even before reactor construction begins. Even with rapid progress, ASN

13. Mark Diesendorf, 2005, ABC 'Ask an Expert', www.abc.net.au/science/expert/realexpert/nuclearpower/03.htm
14. Keith Barnham, 5 Feb 2015, 'False solution: Nuclear power is not 'low carbon'' www.theecologist.org/News/news_analysis/2736691/false_solution_nuclear_power_is_not_low_carbon.html
15. German Environment Ministry, March 2006, 'Atomkraft: Ein teurer Irrweg. Die Mythen der Atomwirtschaft'.
16. www.gen-4.org/gif/jcms/c_9260/public
17. Peter Rickwood and Peter Kaiser, 1 March 2013, 'Fast Reactors Provide Sustainable Nuclear Power for "Thousands of Years"', www.iaea.org/newscenter/news/2013/fastreactors.html
18. Institute for Radiological Protection and Nuclear Safety, 2015, 'Review of Generation IV Nuclear Energy Systems', www.irsn.fr/EN/newsroom/News/Pages/20150427_Generation-IV-nuclear-energy-systems-safety-potential-overview.aspx
19. World Nuclear Association, 15 Dec 2009, 'Fast moves? Not exactly...', www.world-nuclear-news.org/NN_France_puts_into_future_nuclear_1512091.html
20. www.world-nuclear.org/info/Country-Profiles/Countries-G-N/Japan/ https://en.wikipedia.org/wiki/Monju_Nuclear_Power_Plant#Monju_sodium_leak_and_fire
21. Mycle Schneider, 2009, 'Fast Breeder Reactors in France', *Science and Global Security*, 17:36–53, www.princeton.edu/sgs/publications/sgs/archive/17-1-Schneider-FBR-France.pdf
22. World Nuclear Industry Status Report 2014, www.worldnuclearreport.org/-2014-.html
23. Jim Green and Oliver Tickell, 15 May 2015, 'Finland cancels Olkiluoto 4 nuclear reactor - is the EPR finished?', *The Ecologist*, www.theecologist.org/News/news_analysis/2859924/finland_cancels_olkiluoto_4_nuclear_reactor_is_the_epr_finished.html
24. World Nuclear Association, June 2015, 'Emerging Nuclear Energy Countries', world-nuclear.org/info/Country-Profiles/Others/Emerging-Nuclear-Energy-Countries/

estimates a minimum lead time of 15 years before a new nuclear power plant can be started up in a country that does not already have the required infrastructure.[24]

In addition to reactor construction, further years elapse before nuclear power has generated as much as energy as was expended in the construction of the reactor. One academic report states: "The energy payback time of nuclear energy is around 6½ years for light water reactors, and 7 years for heavy water reactors, ranging within 5.6–14.1 years, and 6.4–12.4 years, respectively."[25]

By contrast, construction times for renewable energy sources are typically months not years, and likewise the energy pay-back period is typically months not years.

Another constraint is bottlenecks in the reactor manufacturing sector. Sharon Squassoni noted in a 2009 paper:

"A significant expansion will narrow bottlenecks in the global supply chain, which today include ultra-heavy forgings, large manufactured components, engineering, and craft and skilled construction labor. All these constraints are exacerbated by the lack of recent experience in construction and by aging labor forces. Though these may not present problems for limited growth, they will certainly present problems for doubling or tripling reactor capacity."[26]

Another constraint is the pattern of ageing nuclear workforces − the 'silver tsunami'.[27] In the UK, for example, a recent government report says that attrition rates in the ageing nuclear workforce are "high and growing" with more than 8,000 new employees a year needed every year for the next six years if the country's ambitious new-build programme is to succeed.[28] In addition, research and training facilities and courses have been on the decline.

A major expansion of nuclear power is theoretically possible over the medium- to long-term. The depletion of uranium resources could be a constraint. According to the World Nuclear Association, the world's present measured resources of uranium (5.9 Mt) in the cost category around 1.5 times present spot prices, are enough to last for about 90 years at the current usage rate of 66,000 tU/yr.[29]

4. NUCLEAR POWER *AND* CLIMATE CHANGE

Countries and regions with a high reliance on nuclear power also tend to have high greenhouse gas emissions. For example, the US operates 99 power reactors with a capacity of 98.8 GW (26% of the world total), with nuclear power generating over 19% of its electricity. Yet the US is one of the world's largest greenhouse polluters both in *per capita* and overall terms.

Some countries are planning to replace fossil fuel-fired power plants with nuclear power in order to increase fossil fuel exports. In such cases any potential climate change mitigation benefits of nuclear power are lost. World Nuclear News reported in 2010 that Venezuela, Russia, and some Middle East countries such as the UAE and Iran would prefer to export oil and gas rather than use them in domestic power plants.[30] Saudi Arabia is another country planning to build nuclear power plants in order to boost fossil fuel exports.[31]

5. CLIMATE CHANGE AND NUCLEAR HAZARDS

Nuclear power plants are vulnerable to threats which are being exacerbated by climate change − discussed in detail in Nuclear Monitor #770.[32]

A 2013 report by the US Department of Energy details many of the interconnections between climate change and energy.[33] These include:

- Increasing risk of shutdowns at thermoelectric power plants (e.g. coal, gas and nuclear) due to decreased water availability which affects cooling, a requirement for operation;
- Higher risks to energy infrastructure located along the coasts due to sea level rise, the increasing intensity of storms, and higher storm surge and flooding;
- Disruption of fuel supplies during severe storms;
- Power plant disruptions due to drought; and
- Power lines, transformers and electricity distribution systems face increasing risks of physical damage from the hurricanes, storms and wildfires that are growing more frequent and intense.

At the lower end of the risk spectrum, there are many instances of nuclear plants operating at reduced power or being temporarily shut down due to water shortages or increased water temperature (which can adversely affect reactor cooling and/or cause fish deaths and other problems with the dumping of waste heat in water sources). Reactors in several countries have been forced to close during heat waves, when they're needed the most. For example, France had to purchase power from the UK in 2009 because almost a third of its

25. University of Sydney / Integrated Sustainability Analysis, 2006, 'Life-cycle energy balance and greenhouse gas emissions of nuclear energy in Australia', A study undertaken for the Department of Prime Minister and Cabinet of the Australian Government, http://pandora.nla.gov.au/pan/66043/20061201-0000/www.dpmc.gov.au/umpner/docs/commissioned/ISA_report.pdf
26. Sharon Squassoni, 2009, 'Nuclear Energy: Rebirth or Resuscitation?', Carnegie Endowment Report, http://carnegieendowment.org/files/nuclear_energy_rebirth_resuscitation.pdf
27. Sylvia Westall, 29 Nov 2010, 'Nuclear's 'silver tsunami'', www.reuters.com/article/2010/11/29/us-nuclear-ageing-idUSTRE6AS1PQ20101129
28. HM Government, 2015, 'Sustaining Our Nuclear Skills, www.nsan.co.uk/system/files/Sustaining%20Our%20Nuclear%20Skills%20FINAL.pdf
29. World Nuclear Association, 8 Oct 2014, 'Supply of Uranium', www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Uranium-Resources/Supply-of-Uranium/
30. World Nuclear News, 11 Nov 2010, 'Venezuela puts nuclear over oil', www.world-nuclear-news.org/NN_Venezuelas_puts_nuclear_over_oil_1111101.html
31. Nick Butler, 7 April 2014, 'The Risks of a Nuclear Saudi Arabia', http://blogs.ft.com/nick-butler/2014/04/07/the-risks-of-a-nuclear-saudi-arabia/
32. Nuclear Monitor #770, 24 Oct 2013, 'Feature: Water & The Nuclear Fuel Cycle', www.wiseinternational.org/nuclear-monitor/770/770-24-october-2013
33. Department of Energy, July 2013, 'U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather', http://energy.gov/downloads/us-energy-sector-vulnerabilities-climate-change-and-extreme-weather

nuclear generating capacity was lost when it had to cut production to avoid exceeding thermal discharge limits.[34]

At the upper end of the risk spectrum, climate-related threats pose serious risks, such as storms cutting off grid power, leaving nuclear plants reliant on generators for reactor cooling. A 2004 incident in Germany illustrates the risks. Both Biblis reactors (A and B) were in operation when heavy storms knocked out power lines. Because of an incorrectly set electrical switch and a faulty pressure gauge, the Biblis-B turbine did not drop, as designed, from 1,300 to 60 megawatts. Instead the reactor scrammed. When Biblis-B scrammed with its grid power supply already cut off, four emergency diesel generators started. Another emergency supply also started but, because of a switching failure, one of the lines failed to connect. These lines would have been relied upon as a backup to bring emergency power from Biblis-B to Biblis-A if Biblis-A had also been without power. The result was a partial disabling of the emergency power supply from Biblis-B to Biblis-A for about two hours.[35]

'Water wars' will become increasingly common with climate change − in particular, disputes over the allocation of increasingly scarce water resources between power generation and agriculture. Nuclear power reactors consume massive amounts of water − typically 36.3 to 65.4 million litres per reactor per day − primarily for reactor cooling.[36]

Jellyfish swarms have caused problems at many nuclear plants around the world.[37] Increased fishing of jellyfish predators and global warming are contributing to higher jellyfish populations. Monty Graham, co-author of a study on jellyfish blooms published in the *Proceedings of the National Academy of Sciences*, blames global warming, overfishing, and the nitrification of oceans through fertiliser run-off.[38]

The Union of Concerned Scientists argued in a 2013 report:

"Low-carbon power is not necessarily water-smart. Electricity mixes that emphasise carbon capture and storage for coal plants, nuclear energy, or even water-cooled renewables such as some geothermal, biomass, or concentrating solar could worsen rather than lessen the sector's effects on water. That said, renewables and energy efficiency can be a winning combination. This scenario would be most effective in reducing carbon emissions, pressure on water resources, and electricity bills. Energy efficiency efforts could more than meet growth in demand for electricity in the US, and renewable energy could supply 80% of the remaining demand."[39]

The REN21 'Renewables 2015: Global Status Report' states:[40]

"All energy systems are susceptible to climate variability and extremes. For example, decreasing water levels and droughts can lead to the shutdown of thermal power plants that depend on water-based cooling systems. Dry periods, alternating with floods, can shift erosion and deposition patterns, altering growth rates of biomass and affecting the quality and quantity of the potential fuel output. The melting of glaciers, induced by temperature increases, can have a negative effect on hydropower systems by causing infrastructure damage from flooding and siltation, as well as affecting generation capacity. The efficiency of solar PV declines with high temperatures and dust accumulation, and most of today's wind turbines shut down in winds exceeding 100 to 120 kilometres per hour.

"Typical responses to reducing system vulnerability involve reinforcing existing infrastructure (including strengthening transmission towers and lines); ensuring redundancy of critical systems; building seawalls around power plants; reducing the need for power plant cooling water; and storing larger quantities of fuel at plants. More innovative strategies include local generation and storage, diversification of energy sources, use of a combination of smart grids and technologies, and improving capabilities to couple and decouple individual systems from the central grid system during emergencies.

"Although renewable energy systems are also vulnerable to climate change, they have unique qualities that make them suitable both for reinforcing the resilience of the wider energy infrastructure and for ensuring the provision of energy services under changing climatic conditions. System modularity, distributed deployment, and local availability and diversity of fuel sources − central components of energy system resilience − are key characteristics of most renewable energy systems. Ultimately, renewable energy systems improve the resilience of conventional power systems, both individually and by their collective contribution to a more diversified and distributed asset pool."

34. Robert Krier, 15 Aug 2012, 'Extreme Heat, Drought Show Vulnerability of Nuclear Power Plants', InsideClimate News, http://insideclimatenews.org/news/20120815/nuclear-power-plants-energy-nrc-drought-weather-heat-water
35. Helmut Hirsch, Oda Becker, Mycle Schneider and Antony Froggatt, April 2005, 'Nuclear Reactor Hazards: Ongoing Dangers of Operating Nuclear Technology in the 21st Century', Report prepared for Greenpeace International, www.greenpeace.org/international/press/reports/nuclearreactorhazards
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38. Glenda Kwek, 11 July 2011, 'Jellyfish force shutdown of power plants', www.theage.com.au/environment/jellyfish-force-shutdown-of-power-plants-20110711-1haa6.html
39. Union of Concerned Scientists, July 2013, 'Water-Smart Power: Strengthening the U.S. Electricity System in a Warming World', www.ucsusa.org/our-work/energy/our-energy-choices/our-energy-choices-energy-and-water-use
40. REN21 (Renewable Energy Policy Network for the 21st Century), 2015, 'Renewables 2015: Global Status Report', www.ren21.net/status-of-renewables/global-status-report

6. WEAPONS PROLIFERATION AND NUCLEAR WINTER

Global expansion of nuclear power would inevitably involve the growth and spread of stockpiles of weapons-useable fissile material and the facilities to produce fissile materials (enrichment plants for highly enriched uranium; and reactors and reprocessing plants for plutonium). Global expansion of nuclear power would lead to an increase in the number of 'threshold' or 'breakout' nuclear states which could quickly produce weapons drawing on expertise, facilities and materials from their 'civil' nuclear program.

Former US Vice President Al Gore has neatly summed up the problem: "For eight years in the White House, every weapons-proliferation problem we dealt with was connected to a civilian reactor program. And if we ever got to the point where we wanted to use nuclear reactors to back out a lot of coal ... then we'd have to put them in so many places we'd run that proliferation risk right off the reasonability scale."[41]

Running the proliferation risk off the reasonability scale brings the debate back to climate change − a connection explained by Alan Robock in *The Bulletin of the Atomic Scientists:*

"As recent work ... has shown, we now understand that the atmospheric effects of a nuclear war would last for at least a decade − more than proving the nuclear winter theory of the 1980s correct. By our calculations, a regional nuclear war between India and Pakistan using less than 0.3% of the current global arsenal would produce climate change unprecedented in recorded human history and global ozone depletion equal in size to the current hole in the ozone, only spread out globally."[42]

Nuclear expansion would also increase the availability of nuclear materials for radioactive 'dirty bombs'. It would also increase the number of potential targets for terrorist attacks or conventional military strikes by nation-states (such as the repeated military strikes and attempted strikes on nuclear sites in the Middle East).

The US National Intelligence Council argued in a 2008 report that the "spread of nuclear technologies and expertise is generating concerns about the potential emergence of new nuclear weapon states and the acquisition of nuclear materials by terrorist groups."[43]

As long ago as 1946, the Acheson-Lilienthal Report commissioned by the US Department of State identified intractable problems:

"We have concluded unanimously that there is no prospect of security against atomic warfare in a system of international agreements to outlaw such weapons controlled only by a system which relies on inspection and similar police-like methods. The reasons supporting this conclusion are not merely technical, but primarily the inseparable political, social, and organizational problems involved in enforcing agreements between nations each free to develop atomic energy but only pledged not to use it for bombs. National rivalries in the development of atomic energy readily convertible to destructive purposes are the heart of the difficulty."[44]

Fissile materials

A May 2015 report written by Zia Mian and Alexander Glaser for the International Panel on Fissile Materials provides details on stockpiles of fissile materials. As of the end of 2013, civilian stockpiles contained 57,070 weapon-equivalents: 61 tons of highly enriched uranium (4,070 weapons), and 267 tons of (separated) plutonium (53,000 weapons).[45] The figures are far greater if plutonium in spent fuel is included.

Harold Feiveson calculates that with an increase in nuclear power capacity to 3,500 GW (compared to 380 GW as of June 2015), about 700 tonnes of plutonium would be produced annually.[46] That amount of plutonium would suffice to build 70,000 nuclear weapons, and if we assume an average 40-year reactor lifespan the accumulated plutonium would suffice to build 2.8 million weapons.

Similarly, the Intergovernmental Panel on Climate Change maps out a scenario whereby nuclear capacity would grow to about 3,300 gigawatts in 2100 and the accumulated plutonium inventory would rise to 50-100 thousand tonnes (IPCC, 1995). That amount of plutonium would suffice to build 5−10 million nuclear weapons.[47]

The challenge is still greater as a result of the practice of plutonium stockpiling. Japan's plutonium stockpiling, for example, clearly fans proliferation risks and tensions in north-east Asia. Diplomatic cables in 1993 and 1994 from US Ambassadors in Tokyo questioned the rationale for the stockpiling of so much plutonium. A 1993 US diplomatic cable posed these questions: "Can Japan expect that if it embarks on a massive plutonium recycling program that Korea and other nations would not press ahead with reprocessing programs? Would not the perception of Japan's being awash in plutonium and possessing leading edge rocket technology create anxiety in the region?"[48]

41. Quoted in David Roberts, 9 May 2006, 'An interview with accidental movie star Al Gore', http://grist.org/article/roberts2/
42. Alan Robock, 14 Aug 2008, 'We should really worry about nuclear winter', *The Bulletin of the Atomic Scientists*, http://thebulletin.org/has-time-come-geoengineering/we-should-really-worry-about-nuclear-winter
43. US National Intelligence Council, 2008, "Global Trends 2025 – a Transformed World", http://web.archive.org/web/20081126005323/http://www.dni.gov/nic/PDF_2025/2025_Global_Trends_Final_Report.pdf
44. Acheson-Lilienthal Report, 16 March 1946, 'A Report on the International Control of Atomic Energy', Prepared for the Secretary of State's Committee on Atomic Energy, Department of State, Publication 2498.
45. Zia Mian and Alexander Glaser, 2015, 'Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production', International Panel on Fissile Materials, http://fissilematerials.org/library/ipfm15.pdf
46. Harold Feiveson, 2001, 'The Search for Proliferation-Resistant Nuclear Power', *The Journal of the Federation of American Scientists*, Volume 54, Number 5, www.fas.org/faspir/2001/v54n5/nuclear.htm
47. Intergovernmental Panel on Climate Change, 1995, 'Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses', Contribution of Working Group II to the Second Assessment of the IPCC, R.Watson, M.Zinyowera, R.Moss (eds), Cambridge University Press: UK.
48. Greenpeace, 1 Sept 1999, "Confidential diplomatic documents reveal U.S. proliferation concerns over Japan's plutonium program", http://web.archive.org/web/20081114064230/http://archive.greenpeace.org/pressreleases/nuctrans/1999sep1.html

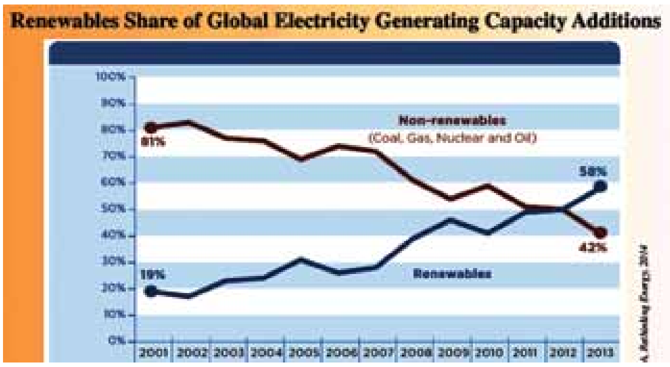
A 2007 report by the International Panel on Fissile Materials (IPFM) states:

"Even a modest expansion of nuclear power would be accompanied by a substantial increase in the number of countries with nuclear reactors. Some of these countries would likely seek gas-centrifuge uranium-enrichment plants as well. Centrifuge-enrichment plants can be quickly converted to the production of highly enriched uranium for weapons. It is therefore critical to find multinational alternatives to the proliferation of national enrichment plants.

"If a large-scale expansion of nuclear power were accompanied by a shift to reprocessing and plutonium recycle in light-water or fast reactors, it would involve annual flows of separated plutonium on the scale of a thousand metric tons per year − enough for 100,000 nuclear bombs." [49]

7. RENEWABLES AND ENERGY EFFICIENCY

The REN21 'Renewables 2015: Global Status Report' details the striking growth of renewables over the past decade.[50] Renewable energy provided an estimated 19.1% of global final energy consumption in 2013, and growth in capacity and generation continued to expand in 2014. Heating capacity grew at a steady pace, and the production of biofuels for transport increased.



Source: World Nuclear Industry Status Report, April 2015.

The most rapid growth, and the largest increase in capacity, occurred in the power sector, led by wind, solar PV, and hydropower. Renewables accounted for approximately 59% of net additions to global power capacity in 2014, with significant growth in all regions of the world.

Global renewable power capacity − excluding hydro − grew eight-fold from 85 GW in 2004 to 657 GW in 2014. Solar PV capacity has grown at a phenomenal rate, from 2.6 GW in 2004 to 177 GW in 2014. Over the same period wind power capacity increased from 48 GW to 370 GW.

Global renewable power capacity − including hydro − more than doubled from 800 GW in 2004 to 1,712 GW in 2014 (an estimated 27.7% of the world's power generating capacity in 2014).

In 2014, total installed renewable capacity (including hydro) increased by 8.5%, compared to 0.6% for nuclear power. Hydro capacity rose by 3.6% while other renewables collectively grew nearly 18%.

By way of sharp contrast, nuclear power has flatlined for the past two decades. Nuclear power capacity was 365 GW in 2004 and 376 GW in 2014, and the number of reactors declined from 443 to 439 over that period.[51]

Renewable capacity (including hydro) of 1,712 GW is 4.6 times greater than nuclear capacity of 376 GW.

But the capacity factor of some renewables (e.g. solar PV and wind) is lower than that of nuclear power, so how do the figures stack up when comparing electricity generation? The REN21 report states that as of the end of 2014, renewables (including hydro) supplied an estimated 22.8% of global electricity (hydro 16.6% and other renewables 6.2%). Nuclear power's share of 10.8%[52] is less than half of the electricity generation from renewables − and the gap is widening.

Renewables jobs have also increased dramatically, with more than 7.7 million people now employed in the sector worldwide.

The REN21 report notes that the growth of renewables is being driven by declining costs and that "in many countries renewables are broadly competitive with conventional energy sources." Further, "growth in renewable energy (and energy efficiency improvements) continues to be tempered by subsidies to fossil fuels and nuclear power, particularly in developing countries."

One final point from the REN21 report warrants mention. The report states: "Despite rising energy use, for the first time in four decades, global carbon emissions associated with energy consumption remained stable in 2014 while the global economy grew; this stabilisation has been attributed to increased penetration of renewable energy and to improvements in energy efficiency."

Deep cuts

Renewables are leaving nuclear power in their wake. But is the growth trajectory of renewables commensurate with the deep cuts in greenhouse emissions required to avert climate change? The short answer is: no.

Could renewables largely supplant fossil fuelled power plants if there was the political will to make the transition

49. International Panel on Fissile Materials, 2007, 'Global Fissile Material Report 2007', Chapter 7, http://fissilematerials.org/library/gfmr07.pdf
50. REN21 (Renewable Energy Policy Network for the 21st Century), 2015, 'Renewables 2015: Global Status Report', www.ren21.net/status-of-renewables/global-status-report/
51. International Atomic Energy Agency, 'Nuclear Power Capacity Trend', www.iaea.org/PRIS/WorldStatistics/WorldTrendNuclearPowerCapacity.aspx
52. Mycle Schneider, April 2015, World Nuclear Industry Status Report, http://static1.1.sqspcdn.com/static/f/356082/26159765/1429631468703/20150415MSC-WNISR2014-WUS-Quebec.pdf

happen? Or is an 'all of the above' approach including renewables and nuclear necessary? There is a growing body of research on the potential for renewables to largely or completely supplant fossil fuels for power supply globally.[53]

Of particular interest are:

• countries with a large number of reactors − only France (58) and the US (99) have more than 50 power reactors;

• countries with a very heavy reliance on nuclear power (e.g. nuclear supplies around 75% of France's electricity); and

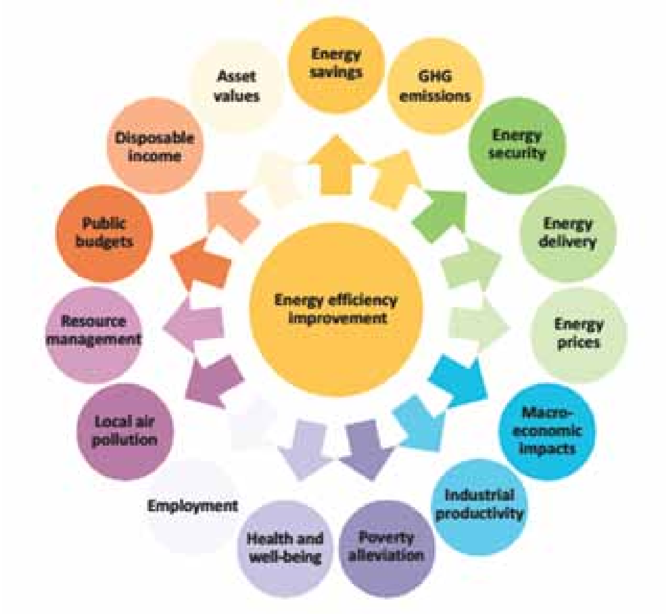
• countries with very large and growing populations and increasing energy demand (e.g. India and China).

USA: The Nuclear Information & Resource Service maintains a list of reports demonstrating the potential for the US (and Europe) to produce all electricity from renewables.[54]

France: A recent report by ADEME, a French government agency under the Ministries of Ecology and Research, shows that a 100% renewable electricity supply by 2050 in France is feasible and affordable.[55] For an all-renewables scenario, the report proposes an ideal electricity mix: 63% from wind, 17% from solar, 13% from hydro and 7% from renewable thermal sources (including geothermal energy). The report estimates that the electricity production cost (currently averaging 91 euros per MWh) would be 119 euros per megawatt-hour in the all-renewables scenario, compared with a near-identical figure of 117 euros per MWh with a mix of 50% nuclear, 40% renewables, and 10% fossil fuels.

China: A 2015 report by the China National Renewable Energy Centre finds that China could generate 85% of its electricity and 60% of total energy from renewables by 2050.[56]

India: A detailed 2013 report by WWF-India and The Energy and Resources Institute maps out how India could generate as much as 90% of total primary energy from



Source: International Energy Agency.

renewables by 2050.[57] The study develops and evaluates a potential growth path involving large deployment of renewables − especially solar, wind and hydro − for electricity generation, with second-generation and algal biofuels meeting the additional demands of the transport sector. It argues that aggressive efficiency improvements also have large potential and could bring in savings of the order of 59% by 2050.

Twin Pillars: Energy efficiency and renewables

A June 2015 report by the International Energy Agency (IEA) compares an 'INDC' scenario, based on 'Intended Nationally Determined Contributions' nominated by (some) countries in advance of the UN climate conference in December 2015, with a more ambitious 'Bridge Scenario'.[58] Energy efficiency does much of the heavy lifting in reducing energy-related greenhouse emissions in the Bridge Scenario compared to the INDC scenario. Energy efficiency accounts for 49% of the

53. Mark Z. Jacobson and Mark A. Delucchi, Nov 2009, 'A Plan to Power 100 Percent of the Planet with Renewables', *Scientific American*,
www.scientificamerican.com/article/a-path-to-sustainable-energy-by-2030/
www.scientificamerican.com/article/powering-a-green-planet/
Mark Z. Jacobson and Mark A. Delucchi, July/August 2013, 'Meeting the world's energy needs entirely with wind, water, and solar power', *Bulletin of the Atomic Scientists* 69: pp.30-40, http://thebulletin.org/2013/julyaugust/meeting-world%E2%80%99s-energy-needs-entirely-wind-water-and-solar-power
WWF International, Ecofys and the Office for Metropolitan Architecture, 2011, 'The Energy Report: 100% Renewable Energy by 2050', http://wwf.panda.org/what_we_do/footprint/climate_carbon_energy/energy_solutions22/renewable_energy/sustainable_energy_report/
Greenpeace International, 'Energy [R]evolution 2012', www.greenpeace.org/international/en/publications/Campaign-reports/Climate-Reports/Energy-Revolution-2012/
A number of other useful reports are listed at the following webpages:
http://go100re.net/e-library/studies-and-reports/
www.mng.org.uk/gh/scenarios.htm
http://go100re.net/e-library/studies-and-reports/ (Global, Europe, America, Asia, Pacific, Others)

54. Nuclear Information & Resource Service, 'Nuclear-Free, Carbon-Free', www.nirs.org/nuclearfreecarbonfree/nuclearfreecarbonfreehome.htm
See also the NIRS 'Alternatives to Nuclear page' resources: www.nirs.org/alternatives/alternativeshome.htm
For European studies see also www.foe.org.au/anti-nuclear/issues/clean-energy/links#3

55. English language summary: Terje Osmundsen, 20 April 2015, www.energypost.eu/french-government-study-95-renewable-power-mix-cheaper-nuclear-gas/
Full report (in French): L'Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME), 2015, 'Vers un mix électrique 100% renouvelable en 2050',
www.ademe.fr/sites/default/files/assets/documents/rapport100enr_comite.pdf
http://fr.scribd.com/doc/261245927/le-rapport-100-energies-renouvelables

56. Article: www.rtcc.org/2015/04/22/chinas-electricity-could-go-85-renewable-by-2050-study/
Report: 'China high renewables 2050 roadmap − summary', www.scribd.com/doc/262740831/China-high-renewables-2050-roadmap-summary

57. WWF India and The Energy and Resources Institute, 2013, 'The Energy Report − India 100% Renewable Energy by 2050', www.wwfindia.org/news_facts/?10261
Summary: Emma Fitzpatrick, 17 Jan 2014, 'Even India could reach nearly 100% renewables by 2051',
http://reneweconomy.com.au/2014/even-india-could-reach-nearly-100-renewables-by-2051-2051

58. International Energy Agency, June 2015, 'World Energy Outlook Special Report 2015: Energy and Climate Change',
www.iea.org/publications/freepublications/publication/weo-2015-special-report-energy-climate-change.html

reduction by 2030, renewables 17%, upstream methane reductions 15%, fossil-fuel subsidy reform 10%, and reducing inefficient coal 9%.[59]

The IEA report's comments on renewables are worth noting. In the Bridge Scenario, 60% of new power capacity between 2015 and 2030 comes from renewables (23% wind, 17% solar PV, 14% hydro, 6% other renewables) compared to just 6% for nuclear, with fossil fuels accounting for the remaining 34%.[60] In the Bridge Scenario, nuclear accounts for 13% of global power capacity in 2030, almost three times lower than renewables' share of 37% (hydro 18%, wind 9%, solar PV, 4%, bioenergy 4%, geothermal 1%, and concentrated solar power 1%).

In the scenario presented in the International Energy Agency's 'World Energy Outlook 2014', which envisages modest efforts to reduce emissions, oil demand in 2040 would be 22% higher without the cumulative impact of energy efficiency measures, gas demand 17% higher and coal demand 15% higher.[61] The report states: "Beyond cutting energy use, energy efficiency lowers energy bills, improves trade balances and cuts CO2 emissions. Improved energy efficiency compared with today reduces oil and gas import bills for the five largest energy-importing regions by almost $1 trillion in 2040."

The REN21 report notes that renewables and energy efficiency are twin pillars of a sustainable energy future − enabling applications that otherwise might not be technically or economically practical and rendering the outcome greater than the sum of the parts. The report provides examples of the synergies:

- Synergies for greater system benefits: Efficient building systems and designs, combined with on-site renewable energy generation, reduce end-use energy demand, electrical grid congestion and losses, and the monetary and energy expenditures associated with fuel transportation.
- Synergies for greater renewable energy share in the energy mix. Improving end-use efficiency and increasing use of on-site renewables reduce primary energy demand. With lower end-use energy requirements, the opportunity increases for renewable energy sources of low energy density to meet full energy-service needs. Targets to increase the share of renewables in total energy consumption can be achieved through both increasing the amount of renewable energy and reducing total energy consumption.
- Synergies for greater investment in renewables and efficiency. Improvements in end-use energy efficiency reduce the cost of delivering end-use services by renewable energy, and the money saved through efficiency can help finance additional efficiency improvements and/or deployment of renewable energy technologies. These synergies exist across numerous sectors, from buildings and electrical services to transportation and industry.

A 2011 study by University of Cambridge academics concluded that a whopping 73% of global energy use could be saved by practically achievable energy efficiency and conservation measures.[62] Julian Allwood, one of the authors of the study, said: "We think it's pretty unlikely that we'll find a good response to the threat of global warming on the supply side alone. But if we can make a serious reduction in our demand for energy, then all the options look more realistic."[63]

59. Ibid., p.74
60. Ibid., p.155
61. International Energy Agency, 'World Energy Outlook 2014', www.worldenergyoutlook.org/publications/weo-2014
62. Jonathan M. Cullen, Julian M. Allwood, and Edward H. Borgstein, Jan 2011, 'Reducing Energy Demand: What Are the Practical Limits?', *Environmental Science and Technology*, 45 (4), pp 1711–1718, http://pubs.acs.org/doi/abs/10.1021/es102641n
63. Helen Knight, 26 Jan 2011, 'Efficiency could cut world energy use over 70 per cent', www.newscientist.com/article/dn20037-efficiency-could-cut-world-energy-use-over-70-per-cent.html

WISE/NIRS Nuclear Monitor

The World Information Service on Energy (WISE) was founded in 1978 and is based in Amsterdam, the Netherlands.

The Nuclear Information & Resource Service (NIRS) was set up in the same year and is based in Washington D.C., US.

WISE and NIRS joined forces in the year 2000, creating a worldwide network of information and resource centers for citizens and environmental organizations concerned about nuclear power, radioactive waste, proliferation, uranium, and sustainable energy issues.

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