Introduction to Nuclear Energy and Weapons in India

India has had functioning nuclear power plants since October, 1969 (NPCIL 2010). India also has a nuclear research programme which has been functional since 1960 (AECL). Initially, India's nuclear technology was all foreign-sourced, coming from the USA (Colors of India) and Canada (AECL). After India's nuclear weapons tests began on the 18th of May, 1974 with Operation Smiling Buddha (NWA) these technology links were cut by India's foreign partners. India's civilian and military nuclear programs continued to expand, however: the civilian program used the Canadian Deuterium-Uranium, or CANDU design to lead its expansion of Pressurized Heavy Water Reactors, PHWRs (Bajaj and Gore 2006), while the military and research sector was lead by the Bhabha Atomic Research Centre, BARC, founded in 1954 (BARC), and the Indira Gandhi Centre for Atomic Research, IGCAR, established in 1971 (IGCAR 2010). In September 1987, the Nuclear Power Corporation of India Limited, NPCIL, was created and since then has run all of the civilian nuclear power plants in India, along with some of the military designated power reactors (NPCIL 2010).

India is one of three countries which have never been signatories of the Nuclear Non-Proliferation Treaty, or NPT, and is currently one of four countries not abiding by the treaty, the others being Pakistan, Israel and North Korea. India was also the first country outside of the five previously designated nuclear weapons states – the United States, Russian Federation, United Kingdom, France, and China – to detonate a nuclear device. Because of this, India was ostracized from the global nuclear technology and nuclear fuel markets (Godsberg). Due to the restrictions on imports of fissile materials and nuclear technology, nuclear energy accounted for approximately 2.8% of India's electricity generation in 2010, while coal, gas and oil (thermal energy) accounted for 65% of India's electricity generation as of September, 2010. India's total installed capacity was 164,836 Megawatts (MW) in September 2010 (CEA). The corresponding contemporary figure of CO_2 emissions is 1,612,362 thousands of metric tons (1.6 billion metric tons) in 2007 (UNSD 2010).

Background to Energy and CO_2 Emissions in India

Domestic growth projections show India's demand for energy is increasing greatly, and hence it is important that its domestic energy supply keeps up with the demand. India has already begun importing coal from abroad to try and bridge this energy gap. The total tonnage of coal imported for the year ending March 31, 2011 is expected to be around 100 million tons due to this ever-increasing energy demand (Lomax 2010). India's energy consumption is expected to rise nearly 800% to reach 1,300 Gigawatts (GW) in 2050 (Rajesh 2010).

By observing the increase in energy needs, the role nuclear energy will have to play can be determined. First, it can be seen that India's current thermal energy (the primary source of CO_2 emissions) produces roughly 107,134MW of power (65% of the total mentioned earlier, corresponding to just over 1.6 billion tons of CO_2 emissions annually (see Appendix I, Figure I). With extrapolation, if coal is the primary source which bridges the future energy gap (hence, presumed to fulfil 100% of the increase in energy demand) which is roughly 1135GW, thermal energy's share of the Indian energy sector can be seen to reach nearly 96%, provided there is no expansion in other energy sectors (see Appendix I, Figure II). This, of course will not be the case, as other forms of energy, such as solar, wind and other renewable sources will begin take their place in the market in the coming decades, and will reduce India's dependence on coal. These can be factored in: out of the roughly 1135GW expansion by 2050, solar energy will account for about 200GW (McDermott 2009), wind for roughly 200GW, hydropower for almost 125GW and biomass for almost 70GW (Kiran 2007). This would leave an additional 540GW of electricity needing to come from thermal energy (excluding biomass), by 2050, provided there is no expansion in the energy generating capacity of the nuclear sector (see Appendix I, Figure III). This would imply an increase of CO_2 emissions by nearly 500% to reach a figure of almost 9.6

billion tons, in a scenario where thermal energy accounts for just about 50% of energy production. Though this would represent a decrease in thermal energy's share of the energy market, but would still imply a large increase in CO_2 emissions simply because of the increase in energy production.

India's Three Stage Nuclear Program and its Relevance

India is poorly endowed with uranium, and its domestic reserves can fuel only 10GW in PHWRs. Further, Indian uranium reserves are of extremely low grade: they contain less than 0.1% fissile uranium compared with 12-14% in certain resources abroad. This makes Indian nuclear fuel 3-4 times costlier than international supplies. India, however, has substantial thorium reserves which can be used, but this requires the thorium to be converted into fissile material, and for thorium-based reactors to be fully researched (Dadhich et al. 2010).

In this context, a three-stage nuclear power programme is envisaged. This programme consists of setting up PHWRs in the first stage, Fast Breeder Reactors (FBRs) in the second stage and reactors based on the thorium cycle in the third stage. It is also envisaged that in the first stage of the programme, capacity addition will be supplemented by electricity generation through Pressurized Water Reactors (PWRs), initially through imports of technology, with the long-term objective of domestic self-reliance. PHWR technology was selected for the first stage, as these reactors are efficient users of natural uranium (the 0.1% fissile uranium which is domestically available), and yield plutonium fuel required for the second stage FBR programme. The FBRs will be fuelled by plutonium (essentially a waste-product of the PHWRs) and will also recycle the spent uranium from the PHWRs to breed more plutonium fuel for electricity generation. Using thorium as the blanket materials in FBRs will produce fissile Uranium-233 to start the third stage. Research and development on the utilisation of thorium in the third stage is currently in progress (Dadhich et al. 2010).

The first stage has reached maturity, though much later than was initially expected. The introduction of PWRs has also begun, through an inter-governmental agreement between India and Russia for cooperation in setting up of two 1,000MW PWRs. A 40MW Fast Breeder Test Reactor was set-up in 1985 to gain experience in the technology under the second stage. Its success has been followed by progress in the development of technology for the first Prototype Fast Breeder Reactor, of 500MW capacity, which should be operational by late 2010 to early 2011 (Dadhich et al 2010).

The FBR technology is critical to developing stage two of India's nuclear power programme. Without developing the wide-scale use of FBR technology, India would find it difficult to go beyond 10GW nuclear capacity based on known domestic uranium resources. The use of FBR technology would enable domestic uranium resources to support a 20GW nuclear power programme by the year 2020. This programme is critical to developing the thorium-based third stage of India's nuclear power programme. BARC is also engaged in research and development activities to develop Advanced Heavy Water Reactors of 300MW capacity that could provide an alternative route to the thorium-based third stage of India's nuclear power programme (Dadhich et al. 2010).

What are the implications of the Indo-US nuclear deal (the 123 agreement) and the subsequent Civil Liability for Nuclear Damages Bill with regards to global CO_2 emission reduction targets?

It may have ended up being the case that in 2050, thermal energy (primarily coal) would account for half of India's energy generating capacity. The signing of the 123 civilian nuclear cooperation agreement between India and the United States, however, prevented this scenario. Under the scenario in which the 123 deal had not been signed, India's domestic nuclear energy generating capacity would probably be capped at slightly over the 20GW level achievable in 2020 (Dadhich et al. 2010). India, which does not have International Atomic Energy Agency (IAEA) safeguards on all its nuclear facilities and nuclear material, detonated a "peaceful" nuclear device in 1974, convincing the world of the need for greater restrictions on nuclear trade. The US created the Nuclear Suppliers Group, or NSG, as a direct response to India's test, and stopped all nuclear exports to India. The US worked to convince other countries to do the same. India's most recent nuclear weapons test was in 1998 (Squassoni 2006).

On the other hand, non-proliferation experts suggested that the potential costs of nuclear cooperation with India to the US and the global non-proliferation regime may far exceed their benefits. At a time when the US called for countries to strengthen their domestic export control laws, US nuclear cooperation with India required loosening its own nuclear export legislation, along with creating a NSG exception. This goes against nearly three decades of US non-proliferation policy. Some believe that the agreement undercuts the basic bargaining power of the NPT, and could undermine the tough to attain restrictions on nuclear supply. The agreement may also prompt some suppliers, like China, to justify supplying nuclear material and technology to other countries outside the NPT regime, like Pakistan. Others believe that allowing India access to the international uranium market will free up its domestic uranium sources to make more nuclear weapons (Squassoni 2006).

The 123 deal, signed in 2008, saw a "paradigm shift in US foreign policy" (Hosur 2010). Before the deal, several steps had to be taken by the US, given India's status as a non-signatory to the NPT. Following the Indo-US nuclear agreement in July 2005 between President George W. Bush and Prime Minister Manmohan Singh, the Henry J. Hyde US-India peaceful atomic energy cooperation act was passed in Congress in December of 2006, making nuclear cooperation part of US law (Paul 2007). According to observers, it was "one of many steps towards India's recognition as a nuclear state, entitled to full civilian cooperation with the [NSG]," (Chanana 2006). Subsequent to this, and prior to the revisiting of this issue in Congress, India had to seek IAEA approval, achieved in August 2008 (Bagchi 2008) and the US had to seek approval from the NSG, achieved in September 2008 (CNN-IBN 2008).

The 123 agreement gives India access to civilian nuclear technology and is supposed to help India fulfil its energy requirements. At the same time, India placed 14 of its reactors under IAEA safeguards and agreed to separate its civilian and military reactors, which had not been done before (Hosur 2010). This distinction of reactors, with all new foreign built reactors under the civilian sector to be under IAEA safeguards, will free up all of India's domestic uranium resources for research into its three-stage nuclear plan (Dadhich et al. 2010).

With this in mind, the Civil Liability for Nuclear Damages Bill of 2010 had to be passed in Indian Parliament in the Monsoon Session of 2010. This bill outlines many important points with regard to liability in the case of a nuclear incident. The bill defines nuclear incidents and nuclear damage, explains who will be liable for nuclear damages, and the financial limits of liability for a nuclear incident. The bill also states that the operator of a nuclear power plant will be liable for nuclear damage caused by a nuclear incident in their installation, or if they are in charge of the nuclear material. The bill further gives operators of nuclear power plants the right of recourse against suppliers responsible for damage under certain conditions (Republic of India 2010). While the liability of any given incident has been capped at 300 million Special Drawing Rights, approximately US$470 million (IMF 2010), the central government has the right to raise this cap, as well as the ₹1,500 crore cap on operators (Republic of India 2010), equivalent to US$336.85 million (Yahoo! Finance, India 2010). These values, hence, are mainly for insurance purposes for nuclear power plant operators and for the central government (PRS 2010).

These legislative pieces in both the US and India opened the doors for international nuclear cooperation with India. For some time, the US had fulfilled its end of the deal, having achieved NSG approval to open nuclear trade with India in September 2008. It took India until August 2010 to pass its civil nuclear liability bill, without which any trade with the US could not occur.

Many global CO_2 reduction targets look to reduce emissions by half their 1990 levels by 2050 (Science Daily 2009). This is ambitious, and for India to stay in par with this goal will require a large-scale effort as India is the third highest contributor to CO_2 emissions, behind China and the US (UNSD 2010). India's projected emissions would need to be vastly slashed: India's CO_2 emissions in 1990 were 0.988 billion metric tons, so halving that would mean reducing emissions to 0.494 billion metric tons by 2050 (Sharma et al. 2006). With current emissions at 1.6 billion metric tons, and potential projected emissions by 2050 without nuclear sector expansion close to 9.6 billion tons, this effectively means reducing emissions to below one-third of the current emissions. A simple answer to this dilemma would be to just not use any more coal and power India's ever-growing economy through nuclear energy and other renewable sources (this, however, is unfeasible and uneconomical), but this brings up a big question: coal has provided India its energy baseline until now – can nuclear energy assume the role of India's baseline energy provider?

Will nuclear energy be able to provide a stable and secure baseline to India's energy needs?

Although some critics believe that the 123 agreement between India and the US will leave India relying on international help in perpetuity, India's three-stage nuclear programme would give India future energy self-dependence. Anil Kakodkar, the chairperson of the Atomic Energy Commission stated in 2008 that should civilian nuclear cooperation begin "and we are able to import 40 Gigawatts of nuclear power production capability between 2012 and 2020," India's projected energy deficit of 400GW out of 1,300GW demand in 2050 can be completely eliminated (Rajesh 2010). This demonstrates clearly how vital nuclear energy is to India's baseline energy needs, but this would also translate to a reduction in carbon emissions. Out of this projected 1,300GW demand in 2050, current nuclear ambitions, according to Indian Prime Minister Dr. Manmohan Singh could boost its nuclear capacity to 470GW by 2050, an increase of over 11,000% compared to the current capacity, potentially making it "the largest expansion of nuclear power in the world" (see Appendix I, Figure IV) (Neuhof 2010). This increase would be crucially dependent on India's use of thorium in stage three of its nuclear vision, involving technologies which are currently still in the research phase in India (Dadhich et al. 2010). By 2016, India's nuclear power generating capacity is already set to double from the present, reaching almost 6% of total electrical power generation in India (NPCIL).

This even outweighs China's aspirations of 300GW installed nuclear capacity in 2050. "Our nuclear industry is poised for a major expansion and there will be huge opportunities for the global nuclear industry," Dr. Manmohan Singh told an atomic energy conference in Delhi. "This will sharply reduce our dependence on fossil fuels and will be a major contribution to global efforts to combat climate change" (Page 2009). The success of the plan would depend on factors including the cost of nuclear reactors, the supply of nuclear engineers in India, the price of fossil fuels and international efforts to impose binding caps on carbon emissions. If nuclear energy were to account for 36.2% of India's energy requirements in 2050 (470GW out of 1,300GW), up from the 2.8% at present, this would represent a major benefit as far as reducing carbon emissions goes, and, it can be strongly argued that this would provide a substantial baseline to India's energy requirements.

Is this a cost-effective way for the US and India to invest in, and draw investment towards, India's energy sector while bearing the need to reduce CO_2 emissions in mind?

Some argue that nuclear energy will only contribute marginally to India's energy in the long run. This is in part due to the cost of nuclear energy, which may be much higher than other conventional sources such as coal, or even compared to renewable sources. However, the fact remains that India's energy needs are so immense that there is no option besides looking at every source to fulfil its energy requirements. In addition, according to Hosur, "the future economic costs and consequences of not fulfilling the energy requirement may be worse than the costs involved in harnessing nuclear energy." This can also be accounted for by the fact that the Indian nuclear sector is open to foreign assistance, and is hence an international endeavour (Hosur, 2010).

India has a lot to achieve in economic terms through the nuclear deal. Soon after the 123 deal was cleared by the US congress in 2008, India signed nuclear cooperation deals with France, Russia, Canada (Hosur 2010) and later with the Republic of Korea (Jain 2009). According to Hosur without the 123 deal, India's "scarce uranium reserves would not have been able to sustain its nuclear power plants in the future." The 123 deal allows India to view nuclear energy as a realistic option as it can now import nuclear reactors and nuclear fuel. With fears of inconsistency in nuclear fuel supply, "the US and India have agreed to the maintenance of a nuclear fuel reserve that will protect India against … inconsistency in fuel supply." Though nuclear energy may be expensive initially, the increase in number of reactors should reduce the per kWh price of electricity produced, based on economies of scale. Before the 123 deal, India had been under the sanctions of around 45 countries in the NSG for over thirty years. Therefore no nuclear cooperation was possible, and many Indian nuclear scientists were not allowed to travel in certain European countries. According to Hosur, "This deal ends three decades of nuclear isolation for India."

There are also benefits of this agreement to the US. For example, Hosur states that since the US is guaranteed a stake in nuclear reactor contracts, it will stand to gain from nuclear relations with India. Further, "the US plans to create jobs through the export of nuclear reactors from the US to India" and with the deal's advantages outweighing its disadvantages, both "India and the US will be able to pursue their … economic interests." The 123 deal pushes forward a positive future in mutual cooperation for both India and the US.

In July 2005, US President George W. Bush announced that he would "work to achieve full civil nuclear energy cooperation with India" and would "also seek agreement from Congress to adjust U.S. laws and policies," to promote stability, democracy, prosperity and peace. His administration promoted nuclear cooperation with India as a way to reduce India's CO_2 emissions and its dependence on oil. It was also argued that this cooperation would be pivotal in bringing India into the "nonproliferation mainstream" and would create jobs for US industry (Squassoni 2006).

Policy barriers which still need to be crossed and general conclusions

The world is moving towards a regime where in the near future a tax or cap (or a combination thereof) may be placed on CO_2 emissions, so nuclear energy would become relatively cheaper. Further, France has shown the world that nuclear energy can be reliable as a baseline (providing 75% of its energy and hence attributed to France's very low CO_2 emissions) and is the world's largest net exporter of energy due to its very low generation costs (WNA 2010). The example of France will give a lot of optimism to nuclear investors and supporters of the Indo-US nuclear cooperation agreement, and will provide a stiff challenge to those who oppose the nuclear deal, regardless of their reasons.

Despite the positive, yet daunting, outlook on India's energy future, with nuclear energy playing a key role in providing baseline energy while at the same time reducing CO_2 emissions, it is interesting to note that on July 1, 2010, India did go as far as to set a number of domestic standards to combat climate change. Included in these policies is a ₹50 (about US$1) levy per ton of coal, both domestically produced and imported, which will help fund a National Clean Energy Fund. This levy is expected to generate about US$500 million in the financial year ending in March 2011. Further, a "Perform, Achieve and Trade (PAT) Mechanism" which India's cabinet approved, which will oversee facilities accounting for over half of India's fossil fuel use, and help reduce CO_2 emissions by 25 million tons by the year 2014-15. This is effectively a system which sets an energy efficiency standard, where each facility would be mandated to improve its energy efficiency based on their current level of energy efficiency: more efficient facilities will have to do less, and less efficient facilities will have to do more. The facilities which exceed the mandated amount of savings will be issued Energy Savings Certificates, ESCerts, which can then be sold to facilities finding compliance costs to be too high (MoEF 2010). While the US has neither a tax-policy nor a cap-and-trade policy in place for CO_2, India has already taken this step without the introduction of increased nuclear capacity into the spectrum.

The major piece which remains, however, is the fact that India's nuclear reactors and nuclear fuel which are under IAEA safeguards are currently not open to reprocessing, which is vital to the three-stage programme working to its capacity. The key idea behind reprocessing is that it uses the waste products from the first stage to generate energy, hence producing more energy for the amount of waste generated. This once-through fuel contains 90% of its original energy. This process of "reprocessing" also produces near weapons-grade plutonium, raising fears that widespread reprocessing could increase the risks of nuclear proliferation (Dadhich et al. 2010).

The talks between India and the US on the issue of reprocessing have been approached by both sides, and discussions are ongoing. Under the 123 agreement, India has prior consent to reprocess the spent nuclear fuel. The agreement does stipulate, however, that this right would only come into effect when India establishes a new national facility dedicated to reprocessing safeguarded nuclear material under IAEA safeguards, and comes to an agreement with the US on "arrangements and procedures under which such reprocessing ... will take place in this new facility," (PTI 2009). The main obstacle which remains is that once President Barack Obama concludes a piece of legislation to this effect and brings it before Congress, the legislation will need to be passed by a two-thirds majority in the US Congress. This may be the biggest battle which is left to be fought as far as the legislative process goes. After the success of the Henry Hyde Act of 2006, we can anticipate a similar positive result from the US legislative body. Hence, though this will take some time to come into effect, it can be eagerly anticipated for the future, and may well provide the final step of policy which needs to be taken in order to allow India's nuclear aspirations to progress.

Conclusion

In conclusion, it can be seen that the 123 civilian nuclear cooperation agreement between the US and India is a vital piece of international legislation. This deal not only has implications for India's domestic energy sector, but it has great implications to global CO_2 reduction goals. The 123 deal will allow India to import foreign nuclear technology and nuclear fuel, allowing it to develop its domestic three-stage nuclear programme. This will help greatly India in becoming more self-sufficient, less reliant on fossil fuels, and will provide an alternate baseline for India's energy sector. At the same time, nuclear energy's role in reducing CO_2 emissions in a cost-effective manner is quite clear. This cost-effectiveness will become even more pronounced when global policies look to reduce overall CO_2 emissions through taxes and caps. Nuclear energy will play a role alongside renewable energy sources to provide a greater energy generating capacity in India, as well as in reducing domestic CO_2 emissions. Though emphasis on nuclear energy is not like the coal-tax or PAT Mechanism in that these policies aim to secure the low-hanging fruit of CO_2 emission reductions, the international interest in nuclear energy in India is a signal that this will be the start of a global effort. This case illustrates a success, with a positive combination of politics on a variety of levels. Alternates to coal fuelling India's economy have been sought through domestic legislation through the MoEF's Post-Copenhagen actions, through many bi-lateral agreements between India and the US, Canada, France, Russia and Republic of Korea, and through global efforts involving the NSG and IAEA.

Bibliography

1. Atomic Energy of Canada Limited (AECL). "CANDU Reactors." n.d. Web. 20 October 2010. <http://www.candu.org/candu_reactors.html>

2. Bagchi, Indrani. The Times of India. "N-deal: Getting NSG nod may not be easy." August 2008. Web. 23 October 2010. <http://timesofindia.indiatimes.com/India/N-deal_Getting_NSG_nod_may_not_be_easy/articleshow/msid-3316564,curpg-2.cms>

3. Bajaj, SS. and A.R. Gore. "The Indian PHWR." *Nuclear Engineering and Design* 236 (2006): 701–72. Web.

4. Bhabha Atomic Research Centre (BARC). "Bhabha Atomic Research Centre: Founder: Heritage." n.d. Web. 20 October 2010. <http://www.barc.ernet.in/about/>

5. Central Electricity Authority (CEA). "Government of India: Ministry of Power: Central Electricity Authority." n.d. Web. 20 October 2010. <http://cea.nic.in/>

6. Chanana, Dweep. "The Indo-US Nuclear Deal: A Post-Henry Hyde Act Analysis." *The Discomfort Zone*. Planetd. 18 December 2006. Web. 23 October 2010. <http://www.planetd.org/2006/12/18/the-indo-us-nuclear-deal-a-post-henry-hyde-act-analysis/>

7. CNN-IBN. "The Big Story: NSG clears nuclear waiver for India." September 2008. Web. 23 October 2010. <http://ibnlive.in.com/news/nsg-clears-nuclear-waiver-for-india/73011-3.html?from=rssfeed>

8. Colors of India. "First Nuclear Power Plant in India." n.d. Web. 20 October 2010. <http://www.thecolorsofindia.com/interesting-facts/science-and-technology/first-nuclear-power-plant-in-india.html>

9. Dadhich, P.K., T. Saxena, M.P.R. Mohan, and W.A. Gracias. "Dimensions of Nuclear Energy in India." *TERI circulation.* (2010). Print.

10. Department of Atomic Energy (DAE). “Atomic Energy Establishments in India.” DAE. n.d. Web. 28 October 2010. <http://www.dae.gov.in/publ/indmap.htm>

11. Godsberg, Alicia. Federation of American Scientists. “Treaty on the Non-Proliferation of Nuclear Weapons [NPT].” n.d. Web. 20 October 2010. <http://www.fas.org/nuke/control/npt/>

12. Hosur, Prashant. “The Indo-US civilian nuclear agreement: what's the big deal?” *International Journal* 65.2 (2010): 435-448. Web.

13. Indira Gandhi Centre for Atomic Research (IGCAR). “Government of India: Department of Atomic Energy: Indira Gandhi Centre for Atomic Research.” October 2010. Web. 20 October 2010. <http://www.igcar.ernet.in/>

14. International Atomic Energy Agency (IAEA). “Stakeholder Involvement in Nuclear Issues.” September 2006. Web. 15 July 2010. <http://www-pub.iaea.org/MTCD/publications/PDF/Pub1276_web.pdf>

15. International Monetary Fund (IMF). “SDRs per Currency unit and Currency units per SDR last five days.” October 2010. Web. 26 October 2010. <http://www.imf.org/external/np/fin/data/rms_five.aspx>

16. Jain, S. K. Nuclear Power Corporation of India Limited (NPCIL). “Chairman’s Statement.” August 2009. Web. 28 October 2010. <http://www.npcil.nic.in/pdf/cmd_statment_09.pdf>

17. Jayaraman, K.S., and Declan Butler. “Companies racing into India's nuclear market.” *Nature* 457.7226 (2009): 134-135. Web.

18. Kiran. “Greenpeace’s India 2050 Energy Scenario.” *The Indic View*. Blogspot, 10 April 2007. Web. 21 October 2010. <http://indicview.blogspot.com/2007/04/greenpeaces-india-2050-energy-scenario.html>

19. Lomax, Simon. Bloomberg. “India Coal Imports May Rise to 100 Million Tons on Power Demand.” May 2010. Web. 20 October 2010. <http://www.businessweek.com/news/2010-05-20/india-coal-imports-may-rise-to-100-million-tons-on-power-demand.html>

20. McDermott, Matthew. Treehugger. “India’s Draft Solar Power Plan Sees 200,000 MW Installed By 2050.” June 2009. Web. 22 October 2010. <http://www.treehugger.com/files/2009/06/india-draft-solar-power-plan-200000-mw-installed-by-2050.php>

21. Ministry of Environment and Forests (MoEF). Government of India. “India: Taking On Climate Change – Post-Copenhagen Domestic Actions.” 30 June 2010. Web. 28 October 2010. <http://www.indiaenvironmentportal.org.in/files/India%20Taking%20on%20Climate%20Change.pdf>

22. Neuhof, Florian. Utilities-me. “Lighting up India.” August 2010. Web. 21 October 2010. <http://www.utilities-me.com/article-706-lighting-up-india/1/print/>

23. Nuclear Power Corporation of India Limited (NPCIL). “Nuclear Power Corporation of India Limited: A Government of India Enterprise.” October 2010. Web. 20 October 2010. <http://www.npcil.nic.in/>

24. Nuclear Power Corporation of India Limited (NPCIL). “Plants Under Operation.” September 2010. Web. 20 October 2010. <http://www.npcil.nic.in/main/AllProjectOperationDisplay.aspx>

25. Nuclear Power Corporation of India Limited (NPCIL). “Projects Under Construction.” n.d. Web. 20 October 2010. < http://www.npcil.nic.in/main/ProjectConstructionStatus.aspx>

26. Nuclear Weapon Archive (NWA). “India’s Nuclear Weapons Program – Smiling Buddha: 1974.” n.d. Web. 20 October 2010. <http://nuclearweaponarchive.org/India/IndiaSmiling.html>

27. Page, Jeremy. The Times. “India promises 12,000% boost in nuclear capacity by 2050.” September 2009. Web. 20 October 2010. <http://www.timesonline.co.uk/tol/news/world/asia/article6854501.ece>

28. Paul, T.V. “The US-India nuclear accord: implications for the nonproliferation regime.” *International Journal* 62.4 (2007): 845-861. Web.

29. Press Trust of India (PTI). The Hindu. “N-deal: India says reprocessing talks will take time.” November 2009. Web. 28 October 2010. <http://beta.thehindu.com/news/national/article53980.ece>

30. PRS Legislative Research (PRS). “Bill Summary: The Civil Liability for Nuclear Damage Bill, 2010.” May 2010. Web. 26 October 2010. <http://www.prsindia.org/uploads/media/Nuclear/Summary%20Civil%20Liability%20for%20Nuclear%20Damage%20Bill%20%202010.pdf>

31. Puranik, V.D. “Dealing with Environment, Waste and Safety Aspects of Nuclear Energy in India.” Bhabha Atomic Research Centre (BARC). February 2010.

32. Rajesh, Y.P. Indian Express. “Nuclear deal crucial to meet India’s energy needs: Kakodkar.” July 2010. Web. 20 October 2010. <http://www.indianexpress.com/news/nuclear-deal-crucial-to-meet-indias-energy-needs-kakodkar/333705/2>

33. Republic of India. Parliament. Lok Sabha. *The Civil Liability for Nuclear Damage Bill, 2010*. Monsoon Session. 19-F. New Delhi, August 25, 2010. Print.

34. Science Daily. “Climate Change: Halving Carbon Dioxide Emissions By 2050 Could Stabilize Global Warming.” May 2009. Web. 26 October 2010. <http://www.sciencedaily.com/releases/2009/05/090502092019.htm>

35. Sharma, Subodh, Sumana Bhattacharya and Amit Garg. “Greenhouse gas emissions from India: A perspective.” Current Science 90 (2006): 3. Web.

36. Singh, B.B. “Editorial[:The Indo-US Civil Nuclear Cooperation].” *Atoms for Peace* 2.1 (2008): 1. Web.

37. Squassoni, Sharon. “U.S. Nuclear Cooperation With India: Issues for Congress.” *Congressional Research Service*. (2006). Web.

38. United Nations Statistics Division (UNSD). “Millennium Development Goals Indicators.” June 2010. Web. 20 October 2010. <http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid>

39. Verma, Raghavendra. “India wary of 'game plan': varying interpretations and last minute amendments in the Indo-US cooperation deal have shaken the Indian nuclear establishment and polarised political parties--problems that could derail the whole process.” *Nuclear Engineering International* Oct. (2006): 6. Web.

40. World Nuclear Association (WNA). “Nuclear Power in France.” October 2010. Web. 28 October 2010. <http://www.world-nuclear.org/info/inf40.html>

41. World Nuclear Association (WNA). “Nuclear Power Reactors.” October 2009. Web. 28 October 2010. <http://www.world-nuclear.org/info/inf32.html>

42. Yahoo! Finance, India. “Indian Rupee to U.S. Dollar Exchange Rate.” October 2010. Web. 26 October 2010. <http://in.finance.yahoo.com/currency/convert?>

43. Zia, Mian, A. H. Nayyar, R. Rajaraman and M. V. Ramana. “Fissile Materials in South Asia and the Implications of the U.S.-India Nuclear Deal.” *Science & Global Security* 14.2 (2006): 117-143. Web.

Appendix I - Charts

Figure I

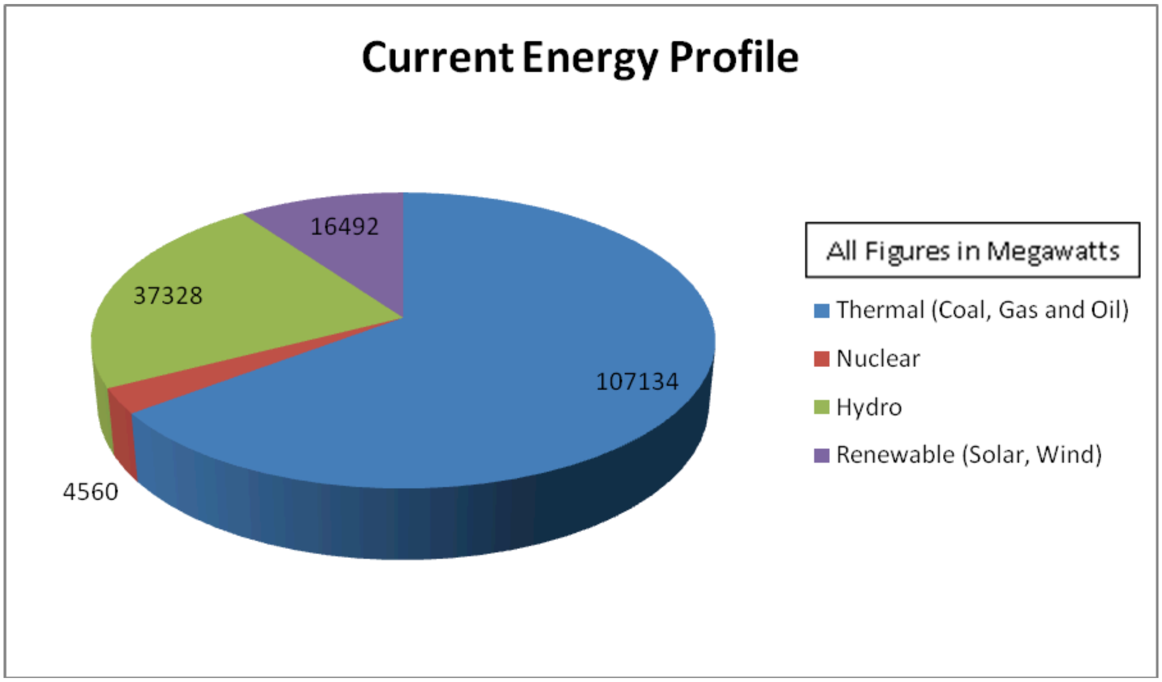

Figure II

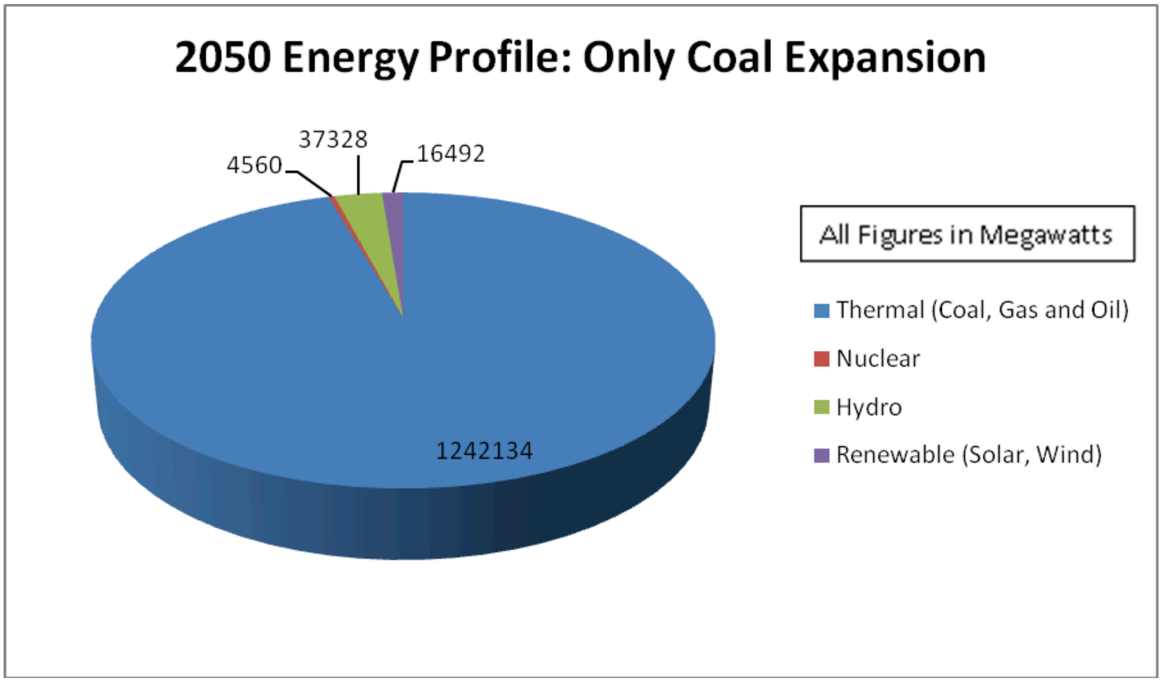

Figure III

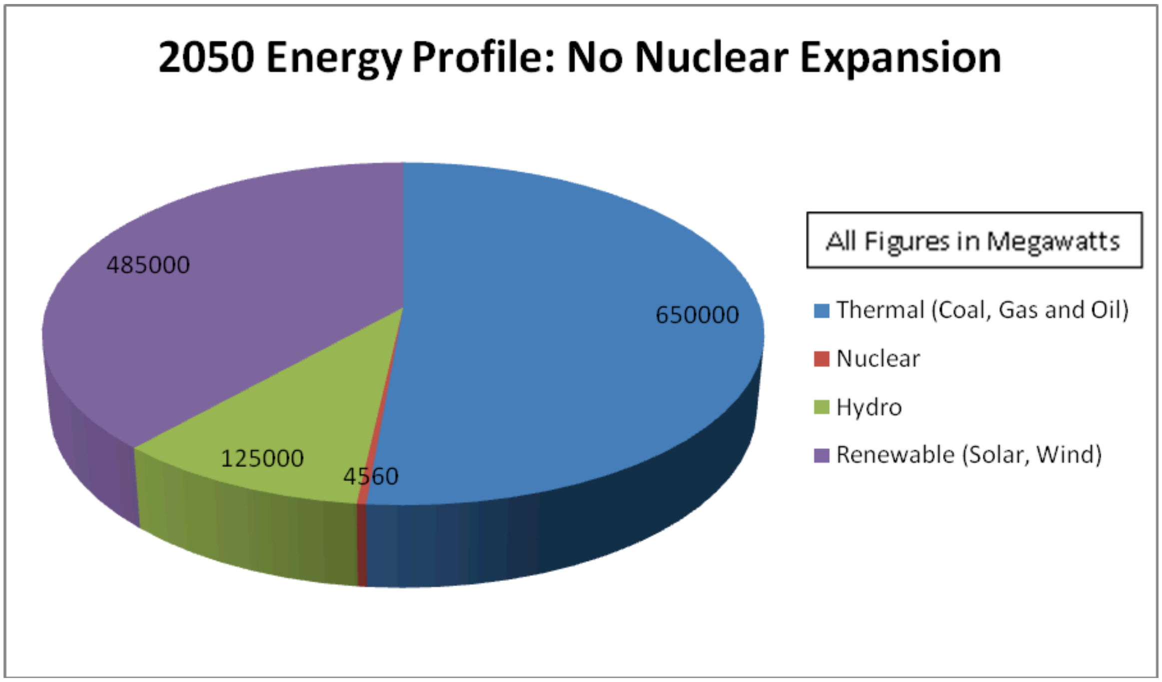

Figure IV