Low Carbon Pathways for India and the World

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Abstract Despite global consensus on the urgent need to limit global warming, firm actions to cap and reverse the level of greenhouse gases in earth's atmosphere are still eluding us. The large scale developmental needs of the developing world and the little carbon space that is available to accommodate them in the business as usual mode clearly requires immediate actions on facilitation and adoption of low carbon pathways by both the developed and the developing countries. In the Indian context, it appears that meeting the anticipated very large growth in energy needs using energy re-sources available within the country, in a sustainable way, would also require adoption of non-fossil energy pathways on a relatively urgent basis. The presentation discusses some approaches towards ensuring sustainable energy supply for meeting development aspirations of a large developing country like India through non-fossil means.

Keywords Nuclear energy · Solar energy · Non-fossil energy · Sustainable energy supply

1 Introduction

International Energy Agency's recently released report, "World Energy Outlook 2015" projects that in the new policies scenario (the central scenario), the global energy demand would grow by nearly one-third between 2013 and 2040, with all of the net growth coming from non-OECD countries and OECD demand ending 3 % lower. Despite signs that a low-carbon transition is underway, energy-related CO_2 emissions are projected to increase to 36.7 Gt in 2040, 16 % higher than in 2013. Climate pledges for COP21, if fully realized including through projected investment needs of $13.5 trillion in low-carbon technologies and efficiency by 2030, could

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possibly mean a temperature rise of 2.7 °C [1]. The efforts thus are not yet enough to move the world onto a pathway consistent with the 2 °C climate goal.

Current total Indian energy use stands at around 0.8 Btoe per year. India's energy demand during this period would see a large rise driven by new infrastructure, an expanding middle class and 600 million new electricity consumers. By 2040, India would close in on United States in terms of energy demand even though demand per capita would remain 40 % below the world average [1]. India is set to contribute more than any other country to the projected rise in global energy demand, around one-quarter of the total. To reach a human development index (HDI) comparable with that in advanced countries (~0.92), India's energy consumption needs to rise to around 4 Btoe per year. Although the total primary energy resources (coal, oil and gas) in India are estimated at around 360 Btoe, actual minable resource (particularly coal) is likely to be much less. The desirable level of energy use to sustain a decent human development index (~0.9+) is unlikely to be sustained (see Table 1) on the basis of available fossil energy resources in the

Table 1 Indian energy resources

Sr. No.	Parameter	Total	Per capita	Remarks
1	Current (2015) energy use per year	0.820 Btoe	640 Kgoe	Most of oil and some gas and coal imported. Import of energy likely to rise steeply (>5–7 times in 15–20 years)
2	Desirable energy use per year	4.125 Btoe	2500 Kgoe	To reach HDI of 0.9+
3	Total primary energy reserves (coal, oil, gas)	361.8 Btoe		Actual mineable is much less. Need technology to make better use of available resource
4	Total renewable potential (incl. hydro, excl. solar) 0.2 Btoe/year	~300,000 MW (peak)		~5 % of requirement
5	Solar resource	~45,000 km^2 which corresponds to a fourth of barren and uncultivable land in India would be sufficient to meet entire electricity requirements (~20 % of total energy requirement)		Needs emphasis on solar thermal (for both electricity and hydrogen)
6	Nuclear resource	Uranium ~87 Btoe Thorium >600 Btoe		On the basis of nuclear recycle

country for a long enough time. Already India imports nearly a third of its energy requirement. Projections are that the energy imports would grow by 5–7 times in next 15–20 years mostly in the form of fossil energy. This clearly would have serious implications in terms of balance of payments. Not only the import bill in absolute terms would be large but the implications of potential volatility would be even larger. Thus quite apart from concerns related to climate change and energy resource sustainability, the implications related to large scale import of fossil energy would also dictate a rather rapid shift to non-fossil energy.

2 Non-fossil Energy

The Table 1 above which has been put together on the basis of available data from different sources also indicates that renewable energy excluding solar but including hydro would constitute about 5 % of the total requirement of 4 Btoe per year. Thus while all these energy sources are important in the short run, we need to aggressively develop solar energy and nuclear energy, both of which are available on the Indian land mass in abundant measure, to ensure sustainable high quality of life of our people.

India's 'intended nationally determined contribution' (INDC) announced before Paris Conference (CoP 21) clearly states the intention to reduce the emissions intensity of its GDP by 33–35 % from 2005 level and to achieve about 40 % cumulative electric power installed capacity from non-fossil fuel based energy resources, by the year 2030, with the help of transfer of technology and low cost international finance, including from Green Climate Fund. An assessment of our current non-fossil electricity generation indicates a generation capacity of 81,757 MWe as on August 2015. By the year 2030, the electricity generation capacity is likely to be around 746 GWe [2]. Thus around 215 GWe non-fossil energy based generation capacity would need to be added in next fifteen years. Government of India has already set a target of generating 175 GWe of renewable energy by the year 2022. Taking this and the expected contributions from nuclear and hydro sector into account, there should be no difficulty in realising the non-fossil energy based generation target as spelt out in our INDC. Looking at the larger problem discussed earlier, we could perhaps do much more.

A question may be raised on the need to pursue both solar and nuclear energy. In this context, it is important to recognise the need to have a basket of energy supply with built in diversity. As it is, in the long run, we have only two options as of now. Besides the two sources have different but complimentary features. One available 24 × 7, the other intermittent. One suitable for decentralised generation, the other for central generation. To en-sure stable operation of the grid in a cost effective way, there should be a minimum base load generation which can more easily be from nuclear plants while distributed solar generation closer to load can help regulation. Concurrent use of both solar and nuclear is therefore inevitable.

There are however challenges that we need to recognise and overcome. For large scale deployment both solar and nuclear energy, establishment of competitive domestic supply chain is a must. In case of nuclear energy, the technology for manufacture of required materials and equipment has been developed for reactor systems like PHWRs and FBRs developed locally. We need to be doing similar thing for reactors based on imported technology. Thus while availability of technology may not be a big issue, the program deployment rate is rather slow. On the other hand, in case of solar, the deployment rate has really picked up but there are difficulties in sustaining manufacturing supply chain with basic raw material manufacture in the country practically non-existent. Since large investments are involved in such programmes, it is important that good part of that money is spent in the country to support local industry and related job creation.

3 Solar Energy

While deploying solar energy, we must invariably attend to specific Indian requirements such as high temperature, high dust level, water scarcity, possibility of abrasion in case of installations located in desserts, uneven terrain in case of installation located in hilly areas and mountains, (both these location choices are otherwise attractive in view of high insolation and relative freedom from land use conflicts) etc. There is also merit in revisiting DC end use appliances running on photovoltaic sources because of their significant potential in terms of better economics as well as better energy efficiency. Cost effective energy storage continues to be the biggest challenge in large scale penetration of solar power.

In case of solar thermal technology, it's potential for competitive 24×7 electricity generation through large capacity plants has not yet been fully recognised. Further, solar thermal technology is inevitable for realising the role of solar energy as primary energy that can be used for both production of electricity as well as for pyro-processes including for production of hydrocarbon substitutes or even hydrogen. An added advantage with solar thermal technology is the possibility of near full indigenisation relatively easily. There is also the possibility to realise viability even with small solar thermal installations with the developments like Brayton cycle and related equipment.

In order to demonstrate solar thermal power generation technologies on MWe scale from where credible extrapolations for viability of large capacity plants can be made, two projects are currently being worked upon. BARC and ONGC are developing a 2 MWe solar thermal beam down facility. Such a facility, since its receiver furnace is located on ground, can also be used to explore the use of solar energy for other pyro-chemical or pyro-metallurgical processes. The other project is being developed by IIT Bombay and NTPC for setting up a 3.5 MWe plant capable of round the clock operation.

Development of solar technology products consistent with specific Indian needs including technologies for their manufacture needs much greater attention. An important strategy could be to promote such technology product development in a demand driven mode by selecting and supporting a few of proposals made jointly by an industry and a laboratory against the requests issued for the purpose. We also need to develop policies that encourage market entry of duly qualified products so developed.

4 Nuclear Energy

The three stage nuclear power programme of our country is well on its way in technological terms. The international embargos that the programme was facing are largely gone without our having to compromise on our strategic autonomy. While we continue to pursue further advancing the technology, the need of the hour is to accelerate programme deployment overcoming the barriers faced. While large scale thorium utilisation remains the key long term objective, there are also possibilities of a more rapid global deployment of nuclear energy leveraging some of the attributes of thorium [3]. Use of thorium matrix fuels in most of existing reactors could well address the concerns related to nuclear proliferation as well as safety and long term waste management without adversely impacting on energy use and economy. India with her advancement in the area of thorium is well placed to take a lead in this context.

Accelerator driven sub-critical reactor systems have the potential to efficiently transmute long lived radio-active species and also permit some growth with thorium fuelled systems. This along with partitioning technologies could also virtually eliminate the long term waste problem. In addition to the technologies related to the three stages of our nuclear power programme, we also need to develop technologies for use of nuclear energy as primary energy source providing high temperature to permit pyro processes as mentioned earlier. We need high temperature reactors for this purpose. Development on these fronts is well underway.

5 Role of Solar and Nuclear Energy as Primary Energy

Apart from developing these two primary energy resources for production of electricity, a major thrust would be needed to produce non-fossil hydrocarbons/hydrogen from these primary resources, so that all segments of energy demand can be addressed. Thus apart from building high temperature capability in solar and nuclear energy technologies, one would require several other technologies such as for production of hydrogen in a more economical way, use of bio-mass and hydrogen for production of hydrocarbon substitutes for use in transportation and other sectors, possibility of recycle of CO_2 through biomass and other modes [4] of CO_2 sequestration, appliances/equipment that can use alternate fluid fuel forms such as hydrogen and a host of such other technologies. Following

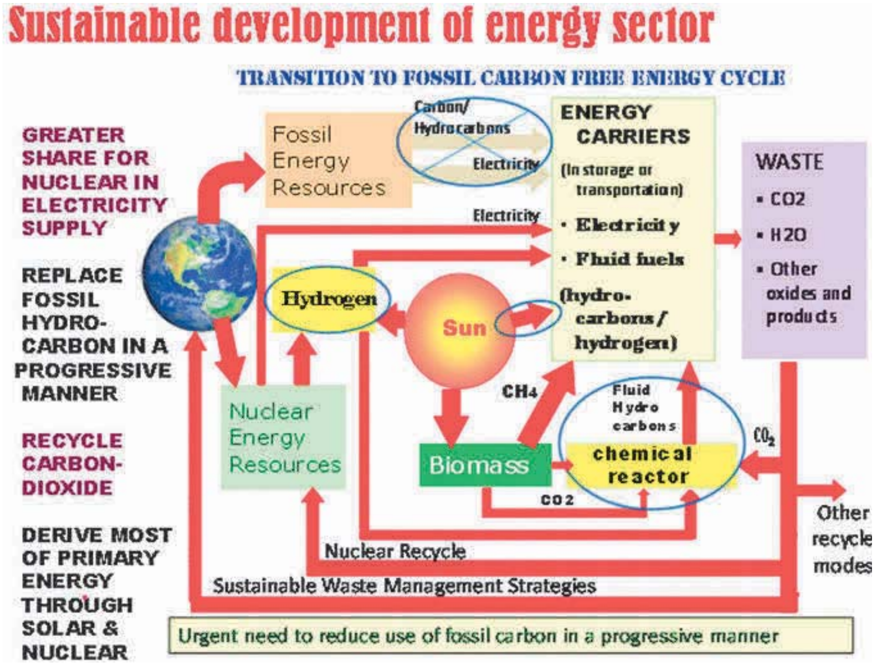

Fig. 1 Transition to fossil carbon free energy cycle

such a strategy, one can indeed make a transition to nonfossil carbon energy cycle, a matter of crucial importance to limiting the global warming. Such a programme needs to be pursued with a time bound mission mode approach (Fig. 1).

6 Concluding Remarks

India's energy challenges are very large with ramifications not just for India but for the whole world. Fortunately the challenge of climate change, sustainability and finance all point towards a common solution. However intense R&D in a mission mode is necessary to develop appropriate solutions and put them in place.

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