VIF Task Force Report

India's Energy Transition in a Carbon-Constrained World: The Role of Nuclear Power

Vivekananda International Foundation

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Overview and Key Recommendations

Overview

The concern for climate change has spurred an intense debate on energy transition to a low carbon economy. Climate change is an existential problem facing humanity. While the developed world has contributed most to global warming, its consequences will be felt by all countries. The worst affected will be those least equipped to deal with it. Vivekananda International Foundation has undertaken a study of energy choices available to India keeping in mind our development perspective.

This is an interdisciplinary study. For this purpose, VIF has put together a Task Force, which consists of senior scientists, engineers, civil servants, and members of academia. Their efforts are supported by a strong research team. The study covers climate negotiations, energy choices made by major economies, and trends in the power sector in India. It explores technology options and finances available to developing countries for making the transition.

This is an interim report. It will be finalized taking into account the outcome of the 26th meeting of the Conference of Parties in Glasgow. The process of writing this report was interrupted by two major developments. The slowing down of winds and increase in gas prices have led to an unprecedented increase in the price of electricity in Europe. The coal shortage threatens to affect the power supply in India. The trend was set by China. The scramble to secure supplies of gas and coal has pushed up the price of fossil fuel, whose demise was being predicted by many experts. Whether these are transient events or underline long-term trends, remains to be seen. However, their significance cannot be ignored. They cover three of the largest economies and point to the difficulty of making the energy transition.

The energy transition to a low carbon economy seeks to break out of the two-century-old historical paradigm since the industrial revolution where economic development was predicated upon the availability of cheap energy. This is not an easy choice. The task is compounded by the fact that the world is still to recover fully from the pandemic. While demand in the developed countries and China has picked up, developing countries will take more time to recover. The economic resources for making the transition will be difficult for them to muster on their own.

In April 2018, 'Leisang in Manipur became the last village to be added to the national power grid.'[1] Though this was indeed a moment to be proud of, India's per capita electricity consumption remains at 1/3rd of the global average. The country's continued growth depends upon access to energy. This points to the complexity of the challenge posed by climate change. The transition to a low-carbon economy involves the diversification of energy sources. This has to be achieved while moving up the development trajectory. India is well on track to achieve the INDCs pursuant to Paris Conference on climate change. Prime Minister Modi has announced further increasing the share of renewables in India's energy basket to 450 GW by 2030.

The UN Secretary-General Antonio Guterres described the findings of the report of the Intergovernmental Panel on Climate Change as 'Code Red for humanity'[2]. The Secretary-General stated:

> 'We need a 45 percent cut in emissions by 2030. Yet a recent UN report made clear that with present national climate commitments, emissions will go up by 16% by 2030. That would condemn us to a hellscape of temperature rises of at least 2.7 degrees above pre-industrial levels. A catastrophe.'[3]

The Secretary General's statement is based on a target of limiting global warming to 1.5 degrees C by the end of the century. What was agreed in the Paris Conference of 2015 was the goal of keeping the rise in global temperature below 2 degrees C, while 'pursuing efforts to limit the temperature rise to 1.5 degrees C. If the lower threshold is accepted, this means a smaller carbon budget and more stringent emission norms. The Secretary-General noted that '.....the OECD just reported a gap of at least $20 billion in essential and promised climate finance to develop countries.' He exhorted the developed countries to show 'more ambition on finance' so that the developing countries finally see 'the promised $100 billion a year for climate action.' He also suggested 'taxing carbon', ending subsidies to fossil fuels, and 'committing to no new coal plants.' Many of these prescriptions are part of the report of the International Energy Agency (IEA). However, their endorsement by the UN Secretary-General gives them greater legitimacy.

The recommendation to 'commit to no new coal plants' has direct implications for India, where coal accounts for more than 71% of India's electricity generation. If the country is to maintain its development trajectory, while moving towards a low carbon economy, solar power is the obvious choice for India. The potential of wind power is limited to coastal states. It is also seasonal. India has already achieved 100 GW in terms of installed capacity. The renewables, however, are intermittent and need to be balanced with stable base-load power. This can either be provided by coal or nuclear in India's case. Given the climate concerns, the share of coal in the energy basket cannot be increased. Hence, the role of nuclear power as a clean, non-fossil source of base-load power assumes significance. There is a positive convergence between the growth of renewables and nuclear power.

IEA report, Net Zero Emission, and Equity

The IEA report on Net Zero Emission states that technologies are available for emission

reduction up to 2030. This still leaves unanswered the question of finance. However, the biggest uncertainty lies in the next phase of de-carbonization. The IEA report admits 'But in 2050, almost half the reductions come from technologies that are currently at the demonstration or prototype phase.' It lists three key areas: 'advanced batteries, hydrogen electrolyzers, and direct air capture and storage.' That these technologies will mature in time and will be cost-effective is a major leap of faith. This cannot be a credible pathway based on what is known to science today.

The concept of Net Zero Emission puts developed and developing countries in a straightjacket despite their widely varying energy, and emission records. India is projected as the third biggest emitter in absolute terms. This methodology ignores that in terms of per capita emission, India is at the bottom of the list amongst major economies. India's per capita emission in 2030 will be less than 1/3rd of the US (30.7%) and about 45% of the Chinese per capita emission. This would be clear from Table 1.

Share of Fossil Fuel

The IEA report suggests that 'no additional new financial decisions should be taken for new unabated coal plants, the least efficient coal plants are phased out by 2030'. While asking developing countries to phase out coal, most developed economies still retain a high share of fossil fuel in their energy basket. In most cases, gas has replaced coal. This is also partly the cause of the current hike in European electricity prices. In Germany, the share of fossil fuel in electricity generation is 40.5%. Of this gas accounts for 16.1%, while the rest is made up of hard coal (7.5%) and mineral oil products (0.7%). In the case of the UK, the share of fossil fuel in electricity generation is 37.7%, with natural gas accounting for 35.5%. A study by Agora Energiewende notes that 'Since 2015,

Table 1 : Per capita annual territorial GHG emissions based on minimum targets:

(tonnes of CO2 equivalent, excluding LULUCF)

Emission levels	2019	2030**
US*	16.06	13
Canada	15.41	12
China	7.10	9
Japan	8.72	7
EU	6.41	5.1
India	1.91	4

Source: UNEP Emissions Gap Report 2020. United Nations Environment Programme; Hannah Ritchie and Max Roser (2020) - "CO_2 and Greenhouse Gas Emissions". *Published online at OurWorldInData.org.* Retrieved from: 'https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions'.

*Projections for the US are based on 2025 projections.

**Approximate projections.

although coal generation halved, (-340 TWh), only half of that was replaced by wind and solar (176 TWh).[4]

Germany and UK have made contrasting energy choices. While Germany has decided to phase out nuclear, the UK is building new nuclear power plants and has even allowed foreign investment. Germany will retain the use of coal (lignite) till 2037, while the UK decided to phase out coal by 2024. Chancellor Merkel towards the end of her term decided to go ahead with the Nordstrom II pipeline, which will import an additional 55 BCM gas per annum. This was done despite the opposition of European neighbors and reservations on part of the US, though Biden Administration eventually acquiesced in the decision. Germany preferred energy security to climate concerns or geo-politics.

The Challenge of Renewables

The recent hike in electricity tariff in Europe demonstrates the volatility and cost of systems based on the high incidence of Variable Renewable Energy (VRE). Natural gas prices were increasing since early this year. The sudden dropping of the wind in the North Sea led to the loss of wind power production. The effect was most pronounced in the UK, though it was felt in the entire European energy market. 'Prices for power to be dispatched the next day rocketed to £285 a megawatt-hour in the U.K. when wind speeds dropped.'[5] 'That is equivalent to $395 a megawatt-hour and marked a record on figures going back to 1999.'[6] There was a sharp jump in electricity prices in Germany also, which reached Euro 131 a megawatt-hour. Germany was relatively protected as it has access to the regional grid and piped gas from Russia.

The impact of the jump in electricity tariff in Europe is continuing to be felt. 'European Central Bank President Christine Lagarde this month referred to energy markets as one of the main forces driving inflation higher'.[7] At least Two U.K. energy retailers went out of business leaving 'a combined 94,000 gas and power customers stranded'.[8] 'National Grid asked Électricité de France SA to restart its West Burton A coal power station in Nottinghamshire. That won't be possible in the future: The government has said all coal plants must close by late 2024'.[9] The problem of the unpredictability of renewables and volatility of imported gas prices has long-term implications for the energy model on which Europe is basing its ambition to attain Net Zero Emission by 2050. Wind accounts for 24% of the UK's electricity generation, while the share of natural gas is 35.7%. In the case of Germany, wind accounts for 23.7% of electricity generation, while natural gas's share is 16.1%. Thus, these two sources account for nearly 60% and 40% respectively of power production in these two countries. Sustained volatility or disruption cannot be easily made up from other sources.

Fatih Birol, IEA Executive Director told the Financial Times that 'There is an inaccurate campaign that's saying we're seeing the first crisis caused by clean energy and that this can become a barrier for further policy action to address climate change. But this is definitely not true.'[10] He claimed that 'the current energy market disruption was due to a confluence of factors, including an "unsustainable recovery" from pandemic, weather conditions and significant gas supply outages.'[11] It is indeed true that an increase in gas prices is a factor in the current crisis. The upward trend in gas prices

pre-dates the dropping of North Sea wind, and fall in wind power generation. However, this does not mean that wind power has played no role in the steep hike in electricity prices. This is partly implicit in Mr. Birol's statement, which refers to 'weather conditions'. The five-fold increase in electricity price took place in September, much before the onset of winter. Therefore, the increase in electricity price did not take place due to the paucity of gas to meet the heating requirement. It took place because gas is used to supplement wind power, and meet balancing or peaking requirements. The sudden drop in wind speed over the North Sea resulted in a sharp drop in the generation, which led to a spike in gas demand. This took place at a time when the international market for gas was tight and led to a jump in prices. Paradoxical, though it may sound, there is a symbiotic relationship between renewable and gas. Increasing penetration of wind power in the grid rests on the availability of fossil fuel. The recent events have underlined the fragility of the model.

The recently released World Energy Outlook by IEA has made an oblique reference to the Texas crisis of February 2021. But it has tip-toed around the ongoing problem in Europe, which has left thousands of consumers stranded in the UK and a series of bankruptcies of power companies unable to cope with the requirement to sell electricity at regulated prices, while the wholesale price of the purchase has gone up steeply. It, however, acknowledges that growing salience of wind and solar energy posing a challenge to Europe's grid stability in the future:

> 'Such vulnerabilities may become more pronounced: in the APS, installed capacity and annual generation from natural gas in both the United States and European Union are lower by 10-25% in 2030, whereas the peak level of weekly gas-fired power generation actually increases by 10-15% relative to 2020, reflecting a much more substantial role for natural gas in balancing variable renewables.[12]

Renewables are important as a source of emission-free energy. But it is disingenuous to talk about it as a problem in the distant future while ignoring its current dimension which is in full public glare. The challenge posed by Variable Renewable Energy will of course get worse as grid penetration increase beyond current levels as acknowledged by the IEA report. This calls into question a key assumption underlying the International Energy Agency (IEA) report on Net Zero Emissions by 2050. The report assumes that 'Electricity accounts for almost 50% of total energy consumption in 2050'**.** It also assumes that **'**By 2050, almost 90% of electricity generation comes from renewable sources, with wind and solar PV together accounting for nearly 70%. A substantially higher percentage of electricity in the overall energy basket, as well as renewables, share in electricity generation would sharply increase volatility.

Integration Cost of Variable Renewable Energy

Chancellor Angela Merkel admitted that Germany's decision to phase out nuclear has made it difficult to meet its climate commitments.[13] Reliance on North Sea winds has costs, which are not reflected in the tariff. This includes balancing costs, which already exceeded Euro 900 million per annum by

2016.[14]In addition, there are considerable costs involved in laying the grid infrastructure. As the salience of Variable Nuclear Energy (VRE) increases, the grid integration costs will go up steeply.

An MIT study has brought out that without the contribution of nuclear power, 'the cost of achieving deep decarbonization targets increases significantly[15]. This is a very significant finding and has relevance for India as we ramp up the share of renewables in the grid by 2030. To optimize the cost, renewable will have to be supplemented with nuclear power. The alternative will be exorbitant whether we chose a renewable-only solution or the European model of depending upon imported gas as the preceding paragraphs have shown.

According to a CEA estimate, the share of renewables in India's power generation will increase from 9.2% at present to more than 31% (Solar 19%, Wind 12%) by 2029-30. With this, the cost of renewable integration will also go up. According to a report by the Forum of Regulators, the cost of VRE integration in the grid, which is not reflected in the present tariff structure of renewables, is Rs. 2.12 kWhr per unit. This includes balancing cost of Rs, 1.02 per kWhr and stranded assets cost of Rs. 1.02 per kWhr. [16] This is borne by the DISCOMs, and eventually passed to the consumers. As India ramps up the renewable capacity from 100 GW at present to 450 GW, this will impose an enormous burden.

Ramping up renewable capacity from 100 GW at present to 450 GW by 2030 will also entail expanding grid. According to an estimate by the Power Grid Corporation, the cost of laying the grid to cover additional renewable capacity (350 GW) will work out to Rs. 2,27,500 Cr (Rs. 2.275 Trillion). If IEA prescription for 90 percent of electricity generation through renewables is accepted to achieve Net Zero Emission target, the cost will be of a much higher magnitude. It will have repercussions across the entire economy and socio-political fabric, and will not be limited to a particular sector alone.

To optimize this cost, without increasing emission, the share of nuclear has to increase. As mentioned earlier, with an almost similar energy profile China is aiming at increasing the share of nuclear to 10% by 2030. The share of nuclear power in the US (20%) and EU (20%) is 10 times higher than its share in India's energy basket (2%).

Though high gas prices are partly responsible for the current crisis in the European electricity market, its role in India's energy transition cannot be ignored. It can supply peaking power. It can also provide balancing power as the salience of renewables in India's grid increases. As we depend upon import, the solution lies in long-term supply contracts and piped gas from neighboring countries to optimize costs.

Finance

According to OECD Secretary-General Mathias Cormann, climate finance in 2019 amounted to $78.3 billion. This was $21.7 billion short of the goal of $100 billion per annum the developed countries had pledged to provide to developing countries.' Even within the existing target, the share of the grant is less than 1/3rd. The OECD statement notes that '...the share of grants in overall public climate finance was 27% in

2019, while loans (both concessional and non-concessional) represented 71%.'[17]

'The goal of $100 billion per annum finance to be provided to developing countries was formalized at COP16 in Cancun, and at COP21 in Paris, it was reiterated and extended to 2025.' [18]This pre-dates the target of Net-Zero Emission. If the new more stringent emission norms are to be accepted, the financing requirement would be considerably higher than $100 billion per annum. According to an estimate by Sri Rajiv Kumar, Vice Chairman, NITI Ayog, India needs 'an outlay of $2.5 trillion on climate adaptation and mitigation projects'.[19]

Winds are changing

The hike in electricity prices in Europe was triggered by a drop in wind speed and an increase in gas prices. It has occasioned a change in Europe's mood. President Macron of France had announced earlier that he would 'shut 14 reactors and cut nuclear's contribution to France's energy mix from 75 to 50 percent by 2035.'[20] He said on 11th October 'We will continue to need this technology.[21] French consumers pay much less for electricity than other EU countries. German households pay 50 percent higher prices than their French counterparts and are above the EU average.

France and many of the Central European countries want nuclear power to be included in the Green Taxonomy to benefit from 'sustainable finance' to be provided by the EU. Recently, France, Poland, Hungary, Slovakia, Bulgaria, Croatia, Romania, and Slovenia said 'To win the climate battle, we need nuclear power.'[22] The statement added 'It is, for us all, a crucial and reliable asset to a low carbon future'.[23]

Perhaps the most significant is the statement by Japan's new Prime Minister Fumio Kishida: It's crucial that we re-start nuclear power plants.' [24]He made the statement in parliament in response to a question by 'Yukio Edano, leader of the main Constitutional Democratic Party of Japan (CDPJ), on the government's policy for sustainable energy and if nuclear power would be part of the plan.'[25] While France and Central European states have been votaries of nuclear power, Japan had closed down nuclear power plants in the wake of the Fukushima incident. The anti-nuclear sentiment has always been strong in that country due to memories of Hiroshima and Nagasaki. Indeed, the process of re-starting the nuclear power plants was started by the previous Japanese government itself. 'The Fifth Basic Energy Plan approved by the Japanese Cabinet in July 2018, calls for nuclear energy to account for 20%-22% of the country's power generation by 2030. [26] Nuclear power is also included in the Sixth Basic Energy Plan approved recently. The process has now accelerated in the wake of climate concerns.

The UK government released an Energy White Paper captioned 'Powering our Net Zero Future' in December 2020. It contained Prime Minister Boris Johnson's Ten Point Plan. The plan included nuclear power along with wind energy as part of the UK's drive towards a Net Zero future. It said 'Nuclear power provides a reliable source of low-carbon electricity.'[27] The paper added 'Our analysis suggests additional nuclear beyond Hinkley Point C will be needed in a low-cost 2050 electricity system of very low emissions.' [28]The British model not only seeks

to revive nuclear power but allows foreign companies to build nuclear power plants. The Chinese company CGTN was part of EDF led consortium to build Hinkley C nuclear power plant. Another Chinese company General Nuclear Power Group (GCN) was to be a minority partner in Sizewell nuclear power plant. Though the participation of Chinese companies in the project is being reviewed by the UK government, the sector remains open to foreign participation.

The UK Government has released an updated document 'Net Zero Strategy: Build Back Greener' in October 2021. This builds on the last year's document. It has added that the UK will 'bring at least one large scale nuclear project to the point of Final Investment Decision by the end of this Parliament.' It has also started discussions to explore the potential of High-Temperature gas Reactors (HTGRs).

The nuclear tariff is fixed on the basis of a system Contract for Difference (CfD). This system also applies to offshore wind power, though the rates are different. Under this arrangement, the government pays the difference between the contract price and the market price in case the market price dips below the agreed strike price. However, if the market price is above the strike price, the operator pays the difference to the government. In its essence, the arrangement provides a long-term price guarantee to the company producing nuclear power or offshore wind power.

Bill Gates in his book *How to Avoid A Climate Disaster* has examined the world's energy options for transition to a low carbon economy. It is a remarkable work. Unlike other studies which tell us about the goals and timelines to be followed, Gates has also discussed *how* to achieve them. He has looked at various technologies available and dispassionately examined their potential to meet the target of Net-Zero Emission. As the founder of one of the world's largest tech companies, who can have better credentials to tell us if these are workable options? He says 'Coal plants are not like computer chips'.[29] 'Unfortunately, no. Computer chips are an outlier.'[30] He adds:

> 'Nor have solar panels become a million times better. When crystalline silicon solar cells were introduced in the 1970s, they converted about 15 percent of the sunlight that hit them into electricity. Today, they convert around 25 percent. That's good progress, but it's hardly in line with Moore's Law.'[31]

This caution about the limits of technology has to be borne in mind while evaluating options and timelines suggested by IEA and a plethora of other Think Tanks. IEA report has candidly admitted that 50 percent of technologies needed to make the transition from 2030 to Net Zero Emission in 2050 do not exist. Given this fact, mathematical models which claim to predict the share of different fuels in pathways to net-zero future, hardly represent scientific rigor.

Gates has also pointed out that de-carbonization of electricity production is only a small part of the problem. Electricity represents only 20 percent of the energy basket. Decarbonization of other sectors of the economy is more difficult even if the share of electricity in the net-zero stage goes up to 50 percent as envisaged in the IEA report. He has discussed the problems of steel and cement production.

These two alone accounts for 10 percent of global emissions. He poses the question 'What's Your Plan for Cement?' he says that the question is just a shorthand reminder that if you're trying to come up with a comprehensive plan for climate change, you have to account for much more than electricity and cars.'

Another key question raised by Bill Gates is *'How Much Space Do You Need?'* This is linked to the issue of land use, which is increasingly one of the most contentious issues the world over, especially in developing countries. He points out that next to fossil fuels, nuclear power is one of the densest forms of energy-requiring much less space than either solar or wind. Nuclear power can provide 500-1000 watts per square meter as against 5-20 watts per square meter for solar and a mere 1-2 watts per square meter for wind power. [32]In other words, for the same energy output, solar would need 100 times space, while wind power will need 500 times space. [33]

On nuclear fission, Bill Gates says:

> 'It's the only carbon-free energy source that can reliably deliver power day and night, through every season, almost anywhere on earth, that has been proven to work on a large scale.
>
> No other clean energy source comes even close to what nuclear already provides today.'[34]

Renewables, particularly solar power has to play a major role in India's energy basket in the future. India has taken major steps to move towards a clean energy future. The Indian government's actions have been acknowledged by the IEA in its World Energy Outlook, 2021:

> 'There have been some notable examples of developing economies mobilizing capital for clean energy projects, such as India's success in financing a rapid expansion of solar PV in pursuit of its 450 GW target for renewables by 2030.'[35]

While ramping up the share of renewables, the systems costs in terms of providing balancing power and grid infrastructure have to be borne in mind. This has to be accompanied by a balanced energy basket. The role of nuclear power in providing stable, baseload power cannot be ignored. As the MIT study noted, its inclusion in the energy mix will help optimize the cost of transition to a low-cost economy.

India also needs gas as a bridging fuel. Indeed, an economy of India's size needs a diversified energy basket. The developed countries have retained gas as a major component of their energy mix. Gas can supply peaking power and supplement the renewables. India has 25 GW of gas-based power plants, which can be used for this purpose. The chapter on *VRE and the Future of Grid* will show, the need for providing 'flexibility will increase. Gas is a cheaper solution than battery storage. As Bill Gates has pointed out, invoking Moore's law to claim that battery costs will become affordable in foreseeable future does not work. This also applies to hydrogen, which is not an energy-dense medium and is difficult to store and transport safely. Hydrogen also involves a two-stage conversion – use of electricity to produce hydrogen through electrolysis and burning of hydrogen to produce electricity. This inevitably leads to a loss of energy. Gas can also fill the transition from coal to nuclear while lowering India's carbon footprint. Will this lead to the

conundrum Europe is facing? This will depend upon the degree of renewable penetration in the grid. What about the cost? If carbon tax becomes a reality, the cost calculus to choose between different energy forms will change. There is no doubt need for caution about the scale of deployment. Gas is also used for City Gas Distribution (CGD) and fertilizer production.

There is growing pressure from the EU to impose a carbon tax. The carbon cost in the EU is currently around Euro 57.98 per tonne. In September, it had crossed Euro 64 per tonne. The EU industry fears that this may lead to the shifting of industries to countries where there is no carbon tax, or it is lower. There are demands from the EU industries to impose a carbon tax to equalize costs between domestic manufacture and imports. The European Commission has proposed a Carbon Border Adjusted Mechanism. It claims that this is designed in compliance with WTO rules. This claim is yet to be tested; at present WTO rules have no such provision. There is, however, no denying that pressure is continuing to build up for environment conditionalities on trade. India has at present a coal cess of Rs. 400 per tonne. The carbon tax will be a major issue at Glasgow Summit in November.

Nuclear power is included in Biden Administration's Clean Energy Standard. The goal is to generate 80% clean electricity by 2030 and 100% by 2035. Recently, US Energy Secretary Jennifer Granholm in her address to the IAEA said that 'We know the continued deployment of nuclear energy is essential to confronting climate change.'[36] Addressing a press conference with DG, IAEA, she stated 'Nuclear is a key technology for the Member States as they aim to lower their emissions, grow their economies, and ultimately combat climate change in a truly sustainable way.'[37] The role of nuclear power in moving towards clean energy has also been endorsed by the EU and UAE. The latter is rich in hydrocarbon resources. Yet, it has decided to invest in nuclear power as a source of clean energy.

Nuclear power will remain a major part of the energy mix of the US (20%), EU (20%), and China (10%) in the future.[38] This is substantially higher than India, where nuclear power accounts for less than 2% of generation at present.

India's energy transition will be a very complex task, particularly since it has to be attempted within the constraints of a Federal structure. This requires political consensus. It also requires restoring the health of the power sector. The energy transition will require massive resources, and there are limits to the budgetary support the governments can provide. The share of renewables, particularly solar has to increase in the energy mix. This has to be complemented with nuclear as a source of clean, base-load power. This is critical in ensuring that the costs are affordable. Without this, it will not be possible to increase the share of electricity in the economy, which is critical to decarbonizing the economy. The country will need adequate transition time. While India is committed to making the contributions it has voluntarily undertaken, it cannot afford to compromise on its development priorities. It is hoped that this study will contribute to making an informed decision by our policymakers.

IEA Reports

The IEA has brought out a number of reports on the subject of climate change lately. This is a welcome change on the part of the organization which was created in 1974 with the stated mandate to preserve the stability of international oil supplies. The reports are rich in useful data. It has advocated the adoption of the Net Zero Emission target by all countries and laid down pathways to achieve this target based on mathematical modeling. But the assumptions on which these reports are based need to be looked at more closely. Some of these are stated.

The IEA report Net-Zero by 2050 – A Roadmap for the Global Energy Sector says:

> 'Most of the global reductions in CO_2 emissions through 2030 in our pathway come from technologies readily available today. But in 2050, almost half the reductions come from technologies that are currently at the demonstration or prototype phase. In heavy industry and long-distance transport, the share of emissions reductions from technologies that are still under development today is even higher.'[39]

> 'The biggest innovation opportunities concern advanced batteries, hydrogen electrolyzers, and direct air capture and storage. Together, these three technology areas make vital contributions to the reductions in CO_2 emissions between 2030 and 2050 in our pathway.'[40]

As the report admits, half the technologies that are needed to reduce emission to net-zero level in 2050 are currently at the demonstration or prototype phase. These include technologies in three key areas – advanced batteries, hydrogen, and electrolyzers. Therefore, to allocate to them share in energy-mix on the basis of mathematical modeling is rather impressionistic. It creates an illusion of certainty where none exists.

While including in mathematical model technologies, which are yet to be proven cost-effective, IEA reports have shied away from acknowledging the cost of providing 'flexibility in generation in a future grid, where the renewables will have a 90% share. The renewables being intermittent, requires creating additional generating assets to back them up. According to World Energy Outlook 2021 by IEA, this requirement will be 'over 170 GW in India (from 40 GW) by mid- century'. This is half the size of India's current grid. An informed discussion of options requires transparency in cost assumptions.

How to Avert A Climate Disaster by Bill Gates

Bill Gates makes a passionate plea for urgent action to avert climate change. But he has displayed a refreshing candor in acknowledging the limitations of technology. He not only suggests the goals to be pursued but also *how* to achieve them. He has posed some key questions. One of these is *What's Your Plan for Cement?* He points out that the production of steel, cement, and plastic accounts for 31 percent of global emissions. This is larger than the share of electricity, which is 27%.[41] In the case of steel and cement, the manufacturing process itself produces carbon-di-oxide. This cannot be averted even if coal or gas is replaced by electricity as a source of heat in production.

Bill Gates keeps returning to the question *How Much Is This Going to Cost?* The cost will be a key factor in the choice of pathways to the energy transition. He has mentioned the MIT study, which points out that an approach solely based on renewables will be extremely costly. This is so not only for developing countries but also for the rich world. Germany and Denmark, which rely upon renewables to provide nearly half the generation have the highest electricity tariff. According to a Bloomberg item, this reached 38 billion dollars in 2020.

Bill Gates has pointed out that unfortunately, the coal plant is not a chip. Nor does Moore's Law apply to batteries. Their costs have come down, but this is nothing of the scale of chips. As the man who founded and ran one of the world's largest technology companies, he is uniquely placed to understand technology.

Bill Gates has analyzed the reason why renewable power is expensive. He says that 'The main culprits are our demand for reliability and the curse of intermittency.' [42] 'The sun and the wind are intermittent sources.[43] 'But our need for power is not intermittent.'[44] This requires either supplementing renewable power with other sources of energy when the sun is not shining and the wind is not blowing. Or the power produced when the weather conditions are alright is stored in batteries. He has argued that this is 'prohibitively expensive.[45]

Bill Gates has advocated nuclear power as the best bet for the de-carbonizing economy while keeping the costs down. Nuclear power is emission-free, reliable technology, 'that has been proven to work on a large scale.' [46] It is much more energy-dense than renewables and takes much less material to build. [47]

Conclusion

Climate change is an existential crisis and demands urgent action. It requires a change in source and uses of energy to reduce carbon footprint. The energy transition of this magnitude in the course of a few decades has never been attempted in the past. It requires recognition of the historical responsibility of the developed countries. They have not only distanced themselves from the principle of special but differential responsibilities, their record of providing financial assistance is also patchy. However, this is not a reason to postpone action on our part. India, like all other developing countries, is already affected by changing weather patterns and natural disasters.

The severity of the electricity price hike in Europe, and the coal crisis first in China and now in India, points to the complexity of the problem. It shows that there is no solution that fits all situations. The renewables are an intermittent source of power, and cannot provide stable base-load power. They also need a backup by gas or coal to provide electricity, when the sun is not shining or the wind is not blowing. This is at the root of the ongoing problem in the UK and some of the European countries, which have witnessed a five-fold increase in electricity prices. Though China and India have similar energy profiles with coal providing the bulk of the electricity consumption, the Chinese per capita emission (9.4 tonnes per annum) is more than four times higher than the Indian level (2.2 tonnes per annum). Having secured a larger share of the global carbon budget, the energy transition will involve less pain for her than India's case, where premature capping will mean lost development opportunity.

Peak emission levels are different for different economies. This means that developed countries and China have not only cornered 80 percent of the global carbon budget, they will continue to appropriate a greater share of the remaining carbon space also. This will perpetuate discrimination and accentuate the disadvantages for the developing countries as the world approaches net zero. The debate in Europe to impose Border Trade Adjustment Tax to avoid 'carbon leakage' ignores this fact. Widely differing peaking levels will leave in place existing asymmetries. China is more than twice the size of the EU in terms of population, and will have nearly double the per capita emission by 2030 (China 9.8 MT and EU 5.3 MT) Though Indian population size is roughly the same as China, its per capita emission will be near 1/4th the Chinese level. China also runs a massive trade surplus with both the EU and the US.

India must ensure that energy transition does not result in foreclosing her development options. Europe's electricity crisis has underlined the cost of increasing penetration of renewables in the grid. Being intermittent, they need to be supplemented by flexible sources of generating power. Combined with the volatile price of imported gas, it has resulted in a steep increase in electricity prices. Currently, the renewables' penetration in the grid ranges from 40-50 percent in the case of the UK and Germany. The problem will be much worse if this level goes up. These costs are difficult for developed economies to meet. In India's case, they will be unbearable.

IEA reports have suggested a 90 percent share of renewables in the grid at the Net Zero Emission stage in 2050, with electricity

providing 50 percent of the energy basket. The IEA reports – Net Zero Emission 2050 as well as the more recent World Energy Outlook 2021, have hinted at the magnitude of the problem for Europe and the US as well as India. But it has shied away from estimating the cost to the economy. In India's case, the report says that 170 GW of flexibility will be required by 2050. This will make electricity prohibitively costly. Successful de-carbonization of the economy requires keeping electricity prices low. As MIT report has suggested, the only way to do so is by including nuclear power in the energy mix.

Recommendations:

1. India has accepted the goal of clean energy and is well on track in achieving her Intended Nationally Determined Contributions (INDC). The Government has announced ramping up the share of renewables to 450 GW by 2030.
2. As part of its INDCs, India had made a commitment at the Paris conference of seeking an 'additional carbon sink' of 2.5 to 3 billion tonnes of CO_2 equivalent by 2030. India achieved 39 million tonnes between 2015 and 2017 and 42 million tonnes between 2017 and 2019 (Total 81 million tonnes). India has to step up the pace at least 12 times to achieve the minimum target of 2.5 billion tonnes.
3. Accelerating adaptive capacity – Community-Based Adaptation forms an important part of the ongoing climate programs in the country in rural, urban and peri-urban spaces, and can become an important part of domestic climate action. Scaling adaptive capacity across population groups can lead to better climate outcomes and palliate disaster risks. These include climate-resilient interventions in the field of agriculture, water resources, energy, and infrastructure. State governments are implementing adaptive action in various sectors by mainstreaming it with Sustainable Development Goals and with climate-resilient local-level planning.
4. Large-scale government programs, such as MNREGA, National Rural Livelihoods Mission, etc., have become important vehicles of enhancing adaptation works, resulting in climate-positive co-benefits. These measures addressing climate vulnerability need to be mainstreamed and highlighted as part of India's development policy frameworks.
5. Mitigation action – Key mitigation action points for the country span the areas of enhancing energy efficiency, increasing the forest carbon stock, knowledge dissemination, and R&D including technological needs aggregation, policies for electric and efficient vehicles in the field of transportation, and diversification of energy sources.
6. India has to bring down the carbon footprints of its economy while moving up the development ladder. De-carbonisation of the economy will require increased electrification of sectors currently dependent upon fossil fuel. This will necessarily imply higher consumption of electricity per head. At present, India's per capita consumption is amongst the lowest in the world. This will have to be ramped up to 15,000 to 20,000 kWhr per capita to cater for a low carbon economy which includes e-mobility, supplying process

heat to industry and hydrogen production. The emission levels of the developed and the developing countries should move towards a convergence.

7. Renewables, particularly solar will have to assume a larger share of India's energy requirements. This has to be done in a fully transparent manner bringing out the cost of the system, including balancing cost and transmission charges, which have to be factored into the tariff structure of the renewables.

8. Renewable power could be deployed as part of distributed generation (preferably in agriculture segment) to minimize the requirement for transmission infrastructure and help reduce the cost. Free/Unmetered power to agriculture constitutes 20 to 40% of the power consumption of most major states. Apart from revenue loss to the DISCOMs, this has led to profligacy in the use of electricity and groundwater resources leading to lowering of the water table in some States with long-term consequences. The farmers could be given solar panels at subsidized rates/free to reduce the pressure on the grid.[48]

9. Nuclear as a source of non-fossil, stable base-load power has to be a significant part of India's energy matrix along with renewables. Major economies like the US, UK, China, Japan, and France have already declared nuclear power as part of their pathway towards a low carbon economy.

10. There is a positive convergence between the growth of renewables and nuclear power. Renewables are an intermittent source of energy and need a source of backup power when the sun is not shining and the wind is not blowing. To avoid increasing import dependence and lower carbon-foot-print, the share of nuclear power has to be increased correspondingly.

11. As the MIT study has pointed out, without the contribution of nuclear power, 'the cost of achieving deep decarbonization targets increases significantly.' An increase in the share of nuclear power is necessitated not only to meet India's additional power requirements but also optimize costs without which the goal of increasing the share of electricity in the energy mix will remain elusive.

12. As part of India's clean energy mix, nuclear power should be given 'must-run status on par with the renewables.

13. Merit Order Dispatch cannot be applied to the nuclear sector as heavy CAPEX requires stable prices.

14. Nuclear power's contribution to grid stability should be factored in the pricing mechanism. Similarly, pricing should factor in the large investment needed to install additional capacity to provide balancing power for renewables, which are intermittent.[49]

15. The nuclear sector should be allowed a level playing field vis-a-vis renewables and provided support on the lines of Renewable Purchase Obligations. Renewable purchase obligation may be converted into non-fossil energy purchase obligation.

16. The nuclear power sector should be exempted from GST on inter-state transfer of goods for project execution. This facility

may also be extended to the equipment supplied by vendors.

17. India needs to achieve a balanced energy basket to ensure energy security, and minimize volatility in electricity prices on account of commodity price fluctuations or weather conditions.

18. As part of its de-carbonization strategy, India needs gas as a bridging fuel. Gas remains a substantial part of the energy mix of developed economies including the US and EU. Though this adds to the import bill, the alternative of development loss cannot be ignored. The energy transition and investment required for this purpose will take time, while there will be strong pressure to cap and phase out coal-based generation. To minimize the impact of international price fluctuations, long-term, stable contracts for the purchase of LNG as well as piped gas from neighboring should be encouraged.

    Gas can also supply peaking power to renewable power plants. Most of the stranded gas-based power plants are based in renewable-rich states.

19. To avoid creating new dependencies, we must build up domestic manufacturing capacity, especially for the renewable sector which is going to witness major expansion.

20. The Government and private sector have to invest in R&D in Green Technologies. India's R&D expenditure has consistently lagged behind international levels. The government should extend funding for R&D for development of SMR reactors as well as load following reactors, which can provide flexible generation.

21. As a dense source of energy, nuclear power can play a role in producing hydrogen through electrolysis as well as through thermochemical splitting of water using high temperature reactors, supplying to long distance heavy vehicle transportation and process heat to industry.

22. Similarly concentrated solar is an important source for hydrogen production through thermo-chemical water splitting route apart from its importance in terms of cheap energy storage for 24/7 electricity generation and should be encouraged.

23. Hydro-power can play a role in providing storage solutions and meeting peaking power requirements. This is inherently limited by land and population pressures. Building up and import of hydro-power from Nepal is a long-term solution. This will be a win-win situation for both countries.

24. The developed countries should be held to their promise of providing financial assistance to developing countries to make the transition to a low-cost economy. The goal of $100 billion per annum assistance is part of the Paris Conference pledge. As noted by the UN Secretary-General, developed countries fell short of reaching even this target. Of the amount provided, 2/3rd consists of credit. This pre-dates the current Net Zero Emission and peaking power concepts, which will result in more stringent emission norms and a shorter transition period. The finance to be provided by the developed countries should match higher ambition for climate action.

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Conclusion and Recommendations

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