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CEEW High-Level Discussion Report

Horizon Energy Technologies, Technology Partnerships, and National Energy Policy

Submitted to NITI Aayog

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Council on Energy, Environment & Water

Summary Report of

High-level Roundtable Stakeholder Discussion on Horizon Energy Technologies, Technology Partnerships, and National Energy Policy

SUBMITTED TO NITI AAYOG

CEEW Report

March 2016

ceew.in

A summary report of high-level roundtable stakeholder discussion on 'Horizon Energy Technologies, Technology Partnerships, and National Energy Policy'.

The high-level roundtable discussion was jointly organised by the Council on Energy, Environment and Water (CEEW), India and the National Institution for Transforming India (NITI Aayog), Government of India on 20 October 2015 at Room No. 122 (SANGAM), NITI Aayog, Yojana Bhawan, Sansad Marg, New Delhi 110001.

Roundtable discussion coordinated by: Dr Vaibhav Chaturvedi (CEEW), Ms Ankita Sah (CEEW), Mr Rajnath Ram (NITI Aayog)

Editor: Ms Malini Sood

The Council on Energy, Environment and Water (http://ceew.in/) is one of India's (and South Asia's) leading think-tanks with a vast scope of research and publications. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It does so by promoting dialogue and common understanding on energy, environment, and water issues in India and globally through high quality research, partnerships with public and private institutions, and engagement with and outreach to the wider public. Visit us at http://ceew.in/ and follow us on Twitter @CEEWIndia.

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Foreword

At the outset, I wish to place on records my deep appreciation for the initiative taken by CEEW to lead this stakeholder consultation on providing inputs to the National Energy Policy on Technology. In the recent years, technologies have played a very important role in transforming energy markets. The sharp decline in the prices of oil, gas and LED are fine examples of the role that technology has played in sharpening the role of market forces. India has its own complex set of energy problems for which technology could be the game-changer as has been witnessed elsewhere.

The present compilation attempts to look at this issue with a fresh approach. It goes beyond the clichés of our low spend on technology and lack of a close relationship between industry and academia. There is a need to address other issues, too. But it also looks at the institutional mechanisms needed to promote technology development. The very caption which includes the term 'technology partnership' - is a powerful statement that technology development is not merely an academic pursuit or a commercial one – it is a combination of both.

A number of Government's announcements in the energy sector will call for a major technology push. The 175 GW renewable energy programme, reduction in oil import dependency by 2022 - all of the above will have technology underpinnings. Electrical vehicles are yet another domain, which will call for technological interventions. I do hope that the National Energy Policy is able to capture some of these pressing needs of the energy sector as a whole. We will have a lot to thank CEEW for mainstreaming technology in the country's policy statements.

Yours sincerely,

(Anil Kumar Jain)

स्वच्छ भारत
एक कदम स्वच्छता की ओर

About CEEW

The Council on Energy, Environment and Water (http://ceew.in/) is one of South Asia's leading not-for-profit policy research institutions. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high quality research, develops partnerships with public and private institutions, and engages with wider public.

CEEW was ranked in 2015 the best in South Asia in two categories three years running (Global Go To Think Tank Index); among the top 100 out of 6846 think-tanks in nine categories. This included CEEW being featured on a prestigious list of 'Best Managed Think Tanks' and 'Best Independent Think Tanks'. CEEW has also been rated as India's top climate change think-tank in 2012 and 2013 as per the ICCG Climate Think Tank's standardised rankings.

In little over five years of operations, CEEW has engaged in more than 100 research projects, published well over 50 peer-reviewed books, policy reports and papers, advised governments around the world over 160 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on more than 40 occasions, helped state governments with water and irrigation reforms, and organised more than 125 seminars and conferences.

CEEW's major projects on energy policy include India's largest energy access survey (ACCESS); the first independent assessment of India's solar mission; the Clean Energy Access Network (CLEAN) of hundreds of decentralised clean energy firms; India's green industrial policy; the $125 million India-U.S. Joint Clean Energy R&D Centers; developing the strategy for and supporting activities related to the International Solar Alliance; modelling long-term energy scenarios; energy subsidies reform; decentralised energy in India; energy storage technologies; India's 2030 renewable energy roadmap; solar roadmap for Indian Railways; clean energy subsidies (for the Rio+20 Summit); and renewable energy jobs, finance and skills.

CEEW's major projects on climate, environment and resource security include advising and contributing to climate negotiations (COP-21) in Paris; assessing global climate risks; assessing India's adaptation gap; low-carbon rural development; environmental clearances; modelling HFC emissions; business case for phasing down HFCs; assessing India's critical mineral resources; geo-engineering governance; climate finance; nuclear power and low-carbon pathways; electric rail transport; monitoring air quality; business case for energy efficiency and emissions reductions; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; resource nexus, and strategic industries and technologies for India's National Security Advisory Board; Maharashtra-Guangdong partnership on sustainability; and building Sustainable Cities.

CEEW's major projects on water governance and security include the 584-page National Water Resources Framework Study for India's 12th Five Year Plan; irrigation reform for Bihar; Swachh Bharat; supporting India's National Water Mission; collective action for water security; mapping India's traditional water bodies; modelling water-energy nexus; circular economy of water; and multi-stakeholder initiatives for urban water management.

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Executive Summary

The Intended Nationally Determined Contributions (INDCs) submitted by various nations and the subsequent Paris Agreement on climate change announced in December 2015 has decisively put the nations on a path to stringent mitigation of greenhouse gases. The energy sector, biggest emitter of greenhouse gases, has to transform significantly to achieve the global climate goals. India is increasingly gaining prominence in global discussions as the fastest growing consumer of energy and resultant emissions. The impending transformation towards a global low-carbon economy presents many opportunities for India, specifically for innovative energy technologies. Within India however, the focus of energy policy has always been energy access, energy security, and energy affordability. To ensure that 'horizon energy technologies and technology partnerships' are viewed in a strategic way and are pursued within the ambit of India's new national energy policy that is being currently drafted by the National Institution for Transforming India (NITI Aayog), the Council on Energy, Environment and Water (CEEW) and NITI Aayog jointly organised a high level expert stakeholder discussion. The discussion highlighted the need to strategically view future technologies and address the key policy changes required to accelerate technology transfer and to foster technology partnerships. Participants included experts and key stakeholders, including senior experts from the government, academia, industry, and civil society.

The key objective of the discussion was to define the role of the National Energy Policy with a focus on fostering horizon energy technologies that are not yet commercialised. The key messages from the discussion were:

- The role of a national energy policy in shaping horizon energy technologies is critical, and an autonomous national body is required to spearhead this process
- Some of the potential horizon energy technologies could be: energy storage solutions, advance nuclear energy technologies, shale gas extraction technologies, geothermal and wave energy, hydrogen fuel cell vehicles, space cooling technologies, and high speed rail.
- There is a need to collate and synthesise programmes on horizon energy technologies running across departments and ministries.
- The time is ripe for planning and investing in strategic R&D for horizon energy technologies.
- Private-sector participation and private–public collaboration in this discussion needs to be ensured.
- Learning from international experiences and initiatives will be beneficial for India.
- Technology partnerships are going to be critical.
- Funding is critical, and a high-impact funding pool needs to be created for supporting investments in horizon technology research and partnerships.

The expert stakeholders recommend setting up of a dedicated expert committee on horizon energy technologies and technology partnerships, and a dedicated funding pool for promoting research and development on horizon energy technologies. The report also defines the role and constitution of the expert

committee. The expert committee should play an essential role in harbouring and supporting horizon technologies, as an independent entity having broad representation from relevant stakeholders from government, private sector and academia. The expert committee should undertake an in-depth analysis with an ultimate aim of recommending a permanent institutional structure within the ambit of the Government of India that can strategically focus on horizon energy technologies and technology partnerships.

1. Background

Energy is critical to the growth and development of any nation. Given the expectations of India's rapid economic growth, the energy sector has been highlighted time and again as a key sector for the realisation of the country's growth ambitions. However, at this stage, India faces numerous energy challenges. The foremost is the issue of energy access, as millions of Indians live without reliable access to affordable energy. Energy security is another concern. India imports more than 70 per cent of its oil requirements, and imports of coal and gas are increasing year on year. Carbon dioxide emissions and local pollutant emissions are rising as a result of increasing energy use, and limiting these negative externalities is another challenge facing Indian energy policy makers. To address these multiple challenges, there is a critical need for a well-thought-out and visionary energy policy that can address these concerns simultaneously and effectively.

For giving direction to the country's response to imminent energy challenges, the Government of India is in the process of drafting a National Energy Policy (NEP). The NITI Aayog has been tasked with spearheading this effort. Traditionally, India's NEP has addressed important concerns around energy access, energy security, and energy affordability. Making India a leader in the development and commercialisation of energy technology needs to be recognised as another important objective, which until now has not been viewed in a strategic way. The Council on Energy, Environment, and Water (CEEW) has been highlighting the strategic importance of including horizon technologies and technology partnerships within the framework of the NEP. By horizon technologies, we mean energy technologies that are at the early stages of ideation or development both in India and abroad. CEEW has been tasked with contributing to the issue of horizon energy technologies and technology partnerships within the framework of India's NEP, which is being formulated by NITI Aayog. A high-level stakeholder roundtable discussion was organised on 20 October 2015 by CEEW and NITI Aayog in New Delhi in this regard for informing the NEP.

2. Structure of the Roundtable Discussion

Technology is changing and revolutionising the world at a phenomenal speed. It is clear that effectively integrated technology can become a strong tool for developing countries to boost their economic growth. The aim of the High-level Roundtable Stakeholder Discussion was to bring together experts and key stakeholders on a common platform to initiate a discussion on importance of strategic advances in future technologies and to address the key policy changes required to accelerate technology transfer and to foster technology partnerships. The roundtable saw participation from senior experts from the government, academia, industry, and civil society. The detailed list of participants is given in Appendix 1.

The discussion began with opening remarks by Dr Arunabha Ghosh (CEEW), who highlighted the importance of including horizon energy technologies and technology partnerships within the framework of India's NEP, and described the objective of this roundtable discussion. This was followed by welcome remarks by Mr Rajnath Ram (NITI Aayog). Mr Ram informed the participants about the process of formulation of India's NEP and the importance of expert stakeholder discussions for providing inputs to the NEP. Following this, Dr Vaibhav Chaturvedi (CEEW) made a brief presentation highlighting the key issues that needed to be discussed by the participants. Dr Arunabha Ghosh then presented his views on technology partnerships based on his recent research on energy and climate technology partnerships. The floor was then made open for discussions on the issues of horizon energy technologies and technology partnerships. The half-day roundtable workshop was concluded by summary comments by Dr Chaturvedi, who highlighted the key themes that emerged from the discussion. Dr Chaturvedi also highlighted that in order to begin the process of institutionalising policy making and planning on the strategically important issue of horizon energy technologies, there is a need to constitute an independent and autonomous expert committee with a clear mandate and a well-defined set of objectives. Details about this proposed committee are given in the section on recommendations. The summary remarks were followed by a vote of thanks by Mr Ram to the participants who had devoted their valuable time, effort, and expertise to contribute to the discussion on this critical issue.

3. Key Messages and Discussion Outcomes

3.1 The role of a national energy policy in shaping horizon energy technologies is critical, and an autonomous national body is required to spearhead this process

India has many programmes and policies aimed at fostering the development of science and technology. However, these initiatives are not specific to energy technologies. It is important to have a separate and exclusive focus on horizon energy technologies as well, and India's NEP can play a key role in institutionalising this process. The following are the key takeaways from the stakeholder discussion on this issue.

- Horizon energy technologies are by definition technologies that are a long way from being commercialised. Hence, the role of policies in discovering and supporting both horizon technologies as well as beyond-horizon technologies is critical.
- The role of government policy is to support such technologies until a market for these is created. Another important role of policy is to provide long -term signal and direction to private investors and market leaders so that they can start investing in projects headed towards the direction indicated.
- Many horizon technologies are horizon in nature not only for India but also for the rest of the world. If we start our preparations early, India can become a global leader in the commercialisation, research, and deployment of horizon technologies, and can also lead in setting up a global manufacturing base (for example, electric two- and three-wheelers, energy storage devices).
- The policy document should include goals and timelines.
- The policy should be framed with a longer-term vision. It should not focus on addressing only the issues we face today, but should also seek to address future challenges. Hence, the issue of horizon energy technologies is strategic in nature given the longer-term vision required to develop and harness these technologies.
- Along with the longer-term vision, the policy should have near-term, mid-term, and long-term targets against which progress can be measured.
- The policy should be customised in terms of the Indian context, and should avoid incentivising a particular technology. The development of an ecosystem favourable for investment in R&D for high-impact horizon energy technologies should be the priority of the NEP.
- The policy on horizon energy technologies should not be prescriptive in nature.
- It is important to recognise that missions like Make in India cannot be supported with renewables only, which has been the focus of most discussions in India so far. The objective of the NEP should be to look at the larger picture and to develop a wide variety of horizon technologies across sectors.

- India's Intended Nationally Determined Contributions (INDCs) envisage a high share of solar and wind energy, which will be dependent on storage solutions as well as grid-management solutions. These solutions are currently not available in India, and hence it is important to bring these within the purview of the NEP to ensure a strategic push forward.
- India has a low-cost procurement environment which should help in the commercialisation of future energy technologies, giving the country a cost advantage.
- The NEP should enable the Ministry of Finance and the Department of Science and Technology to undertake technology transfer smoothly and expeditiously.
- It is important to work across the energy sub-sectors, spanning both supply side as well as demand side, and to develop a micro-level understanding of each sub-sector so as to initiate collaboration across these for the development of horizon energy technologies.
- It is important to identify areas and sectors that require horizon energy technologies and to prepare a suitable framework to deal with future challenges.
- It is important to benchmark technologies in order to compete effectively with the development of cutting-edge technologies in different countries. The role of the government and the bureaucracy in the benchmarking process is also important.
- Horizon energy technologies and technology partnerships need to be part of India's NEP. Ideally, these should be a separate area of focus (and potentially have a separate chapter devoted to them), along with a focus on energy access, energy security, and energy affordability.
- Ultimately, a permanent national body should be created with a specific focus on horizon energy technologies and technology partnerships, for example, a Cell on Strategic Horizon Technologies (C-SHoT). The process of creating such a permanent national body can be initiated by constituting an expert committee on horizon energy technologies and technology partnerships. Whether this body is an autonomous body, or is governed completely by a government ministry or department, is a matter that should be determined by the expert committee. It is important that this committee be led by non-government experts to ensure autonomy, but it should have representation from all key ministries and departments. Detailed suggestions about the role and constitution of the expert committee are given in the last section on policy recommendations. The committee should not just identify technologies but should also lay down the guidelines for the processes needed to develop and implement them.

3.2 Which are some potential horizon energy technologies?

The objective of this expert stakeholder discussion was not to identify horizon technologies. The process of identification and prioritisation should be based on a set of criteria developed through in-depth stakeholder discussions. Nevertheless, it is important to highlight some of the technologies that could be critical for India in the future.

Supply-Side Technologies

Energy storage solutions: Energy storage is one of the most critical areas of research, given that India has huge ambitions of scaling up intermittent and variable renewable energy technologies. Energy storage solutions will also be required for the development of electric vehicles and for improved grid management through smart grids. Extensive research is currently being conducted on lithium-ion batteries, but new

technologies like solid state batteries are also emerging. The development of energy storage technology should encourage processes that are more environmental friendly. Many new configurations of energy technologies are being tested around the world, and any breakthrough in this area would be important for India as well.

Advanced nuclear energy technologies: Some experts believe that nuclear energy will play a major role in long-term policy in order to support and popularise the adoption of low-carbon energy technologies and to reduce the carbon footprint. Countries around the world are conducting research into many advanced nuclear technologies. Most of these are also passively safe technologies. It is important to have a strategic view about which of these 'advanced' nuclear technologies could be developed as one of the potential horizon technologies.

Shale gas-extraction technologies: India is supposed to have significant reserves of shale gas and oil. However, these reserves have not been explored to the extent required for estimating their potential. Shale oil and gas could be important resources in the future. Extraction technologies have already been developed by US companies. Forging partnerships with these companies is one potential way of getting access to these extraction technologies. Irrespective of the arrangement entered into, this category of technology would be very important for India as a horizon technology.

Geothermal and wave energy: Geothermal energy is not envisaged as being a major contributor to India's power generation mix even in the long term. However, this energy resource could be critical in meeting the energy demand in remote areas, especially hilly regions. Similarly, wave energy is a horizon technology that could be used to harness the power of waves across India's long coastline. Both these are renewable forms of energy and could be very useful for niche applications where it is difficult to supply grid power.

Demand-Side Technologies

Hydrogen fuel cell vehicles: Japanese automotive maker Toyota recently announced its plans to focus on developing hydrogen-powered vehicles. Such vehicles are already present on the road in some countries as part of certain research and pilot-testing programmes. Replacing or even eliminating oil in our transportation system is critical for a cleaner environment. The development of electric-vehicle (EV) technologies is witnessing rapid progress, especially by car companies like Tesla Motors, Inc., the US automotive and energy storage company. The technology of hydrogen-powered vehicles has the potential for changing the transportation sector significantly.

Space-cooling technologies: Research studies and market trends both show that the demand for space-cooling and air-conditioning systems in both residential and commercial operations will increase significantly in the near and long-term future. Air-conditioners, even after significant increases in efficiency, continue to be huge guzzlers of electricity. Given India's focus on developing new cities rapidly in the near future, there is potential for developing cooling technologies like district cooling that can reduce the demand for electricity-intensive space air-conditioning technologies . It is important to think about space cooling in novel and innovative ways so as to meet the potentially massive demand for electricity from India's building sector.

High-speed rail: India has a huge rail network, encompassing many long-distance routes and hundreds of trains. Very recently, the Government of India has approved the Ahmedabad-Mumbai high speed rail cor-

ridor after examining its feasibility. The corridor will be developed with the help of Japan which has also agreed to provide low interest long term loan for the project. As income and purchasing power increase, passenger demand for travel services is bound to grow. This is already being witnessed with the growing air traffic year on year in India. Bullet trains are well placed to meet the demands for long-distance high-speed travel. This technology is already available in other parts of the world and could be important for India in the future.

3.3 Need to collate and synthesise programmes on horizon energy technologies running across departments and ministries

The stakeholders highlighted that programmes on horizon energy technologies are already being implemented in India and research on this subject is also being pursued, but at the same time these programmes and research projects are viewed as individual activities. It would be useful to give these disparate efforts a coherent shape and direction so that the whole becomes larger than the sum of its individual parts:

- Various programmes on technology development are being implemented across ministries and departments.
- Most bilateral programmes are project specific and limited in terms of scope.
- There is, however, no programme that strategically addresses the issue of horizon energy technologies as a group, although there are initiatives around individual technologies.
- Indian organisations are involved in many partnerships with international institutions on a variety of energy technologies.
- If the development of horizon energy technologies is accepted as a strategic issue by the government, then the government should create a separate and dedicated mechanism for pursuing this goal.
- There is clearly a need to synthesise information emerging from the existing set of programmes and activities, and to brainstorm about the future course of strategic planning for the development of horizon energy technologies.
- The NEP is the best-suited policy document for giving a strategic direction to the development of horizon energy technologies by bringing all the related programmes and policies under one umbrella.

3.4 The time is ripe for planning and investing in strategic R&D for horizon energy technologies

India's policy makers have time and again highlighted the importance of innovation and R&D. In developed countries, a great deal of innovation takes place outside the government structure, although significant support and incentives are provided by the government as well. With energy demand set to increase significantly across the world, and with global energy systems poised at the beginning of a significant transition towards cleaner energy sources, the time is ripe for making strategic investments in horizon energy technologies. The following are the key outcomes of the discussion on this issue.

- India's energy policy must focus on R&D. Currently, there are very few government laboratories and India is lagging behind other countries in R&D. This situation calls for India to make a huge technology leap. However, government laboratories should not be the only platforms for the development of horizon energy technologies. India's private sector possesses tremendous expertise and should also be

tapped. The role of the NEP is critical in channelling this expertise of the private sector in a strategic direction.

- The NEP should include education on energy and on energy research. Demonstration centres where technology products are exhibited should be a part of a communication plan that should be integral to the policy. Thus, the policy should not be just about R&D, but should also include a strong public communication component.
- R&D laboratories and research institutions should be encouraged to collaborate and cooperate through symposiums, consortiums, etc.
- Academics should be nurtured, encouraged, and supported to take-up R&D projects.
- It is critical to involve the state governments in ultimately meeting the country's energy-related aspirations and in building the required infrastructure for R&D.
- Deployment of early stage technologies in industries is critical and in the best interest of industries.
- Research needs should be identified by industry experts along with experts from research and academic institutions. Ideally, a consortium with representatives from industry and research institutions should be established.
- Research and academic institutions should seek to discover and present meaningful, workable, cost-effective, and sustainable solutions to the problems.
- Government laboratories should also be evaluated on the number of working research collaborations with other research institutes and industries, not only on the number of publications they issue.

3.5 Private-sector participation and private–public collaboration in this discussion needs to be ensured

Fostering the technical, financial, and managerial expertise of the private sector is an important aspect of fulfilling India's ambition of becoming a leader in the development and commercialisation of horizon energy technologies. There are two channels through which the private sector can participate. One is through collaborations with government agencies. The other is through its own R&D efforts, which are driven by market forces. The NEP should mobilise private-sector participation through both these channels, and these efforts will require different kinds of incentives. The following are the key messages from the stakeholder discussion on this aspect.

- Partnership between government and private research institutions is required for achieving the goal of the development of horizon energy technologies. Collaborations of the government sector with industries, research institutions, and academia are important. Collaboration between private companies and research laboratories can be instrumental in producing cutting-edge R&D (for example, collaboration between General Electric (GE) and the National Chemical Laboratory, Pune).
- There is a need to review and learn from collaborative transnational networks and public–private R&D frameworks.
- Joint ventures between government companies and private sector companies, particularly those companies that possess expertise in horizon energy technologies, should be encouraged.
- The government should send out the right market signals through fiscal incentives encouraging innovation and for increased deployment of technology on the ground.

- The NEP needs to provide support for trials and for risk-taking in the process of innovation. This approach will incentivise private companies and entrepreneurs to invest in the development of horizon energy technologies.
- Providing incentives to Indian industries is an important aspect of the NEP, and the creation of an innovation-friendly ecosystem is critical, irrespective of the availability of opportunities for collaboration between the public and private sectors.
- The issue of intellectual property rights (IPR) needs to be addressed, as this would be key in the private sector deciding whether or not to invest. While the government would be interested in introducing low-cost, easily available technologies for the benefit of the country, the private sector might not be interested in sharing the technologies that they possess or have developed. The NEP should aim at enabling private-sector companies to gain adequate returns for the risks they undertake in the R&D process and for the investments they make.
- The needs of academic and research institutions should be served by industry, for example, in terms of providing funding for high-impact research.
- Meeting corporate social responsibility (CSR) obligations can be used as an opportunity to invest in technology innovation, skill development, and R&D.
- The CSR law dictates that R&D investment that has an indirect benefit on the investor company cannot be considered as CSR spending. This legal requirement is an impediment to R&D in the energy sector.
- Although participation by the private sector is most important, often the promotion of technology development by the private sector may not necessarily contribute to the strengthening of the energy sector. Rather, it could end up contributing only to the individual market interests of private-sector companies and these companies could end up monopolising the new energy technologies being developed, which eventually would make it costlier for the general public to access these technologies. The NEP should highlight this aspect and call for appropriate arrangements to address this concern.
- The adoption of appropriate financial and business models is critical at each stage of the process of energy technology development and commercialisation. In terms of technology applicability, the pace at which change in energy technology is taking place is much faster now than ever before.
- The adoption of appropriate business and financial models has led to an increase in the absorption, adaptation, and application of technologies. Finance from both the private and public sectors is another important enabling condition for the success of any R&D policy.

3.6 Learning from international experiences and initiatives will be beneficial

Many countries, especially those in the developed world, have extensive experience in strategic initiatives involving energy technologies. It is important for the makers of India's NEP to recognise this and to learn from these experiences.

- It will be useful to assess learning based on the experiences of Chile and California, which plan to achieve large-scale energy storage technology penetration to help reduce variability, to control frequency, and to manage peak loads. These lessons and best practices will help India in harnessing its vast potential of renewable energy.

- Germany is a global leader in formulating and implementing policies and programmes for incentivising solar energy. These efforts are also aimed at bridging the gap between innovation and practice. Becoming a global leader in energy technology development requires the development of the necessary skills and capacities. Another requirement is finance, whose role is critical. In Germany, both government and private sector funding are in place to encourage R&D in newer energy technologies.
- The Advanced Research Project Agency-Energy (ARPA-E) programme of the US government is a flagship programme for identifying high-potential high-impact energy technologies. Its success can be gauged from the fact that it has already led to a significant drop in the cost of storage technologies. This programmatic approach offers substantial learning for India in regard to horizon energy technologies.

3.7 Technology partnerships are going to be critical

Technology partnerships can take various forms. They could be between the public and private sectors in India, or between an Indian company and a foreign company, or they could be bilateral or multilateral partnerships between the Indian government and foreign government(s). In addition to assuming various forms, each technology partnership also has its own particular functions and objectives. For example, some partnerships could be focused on innovation, while others could concentrate on the commercialisation of technologies. The forms, functions, and objectives of each technology partnership will depend on the horizon energy technology being developed. The following are the key points on technology partnerships that emerged from the stakeholder discussion.

- India has considerable experience in running and participating in large consortiums, and in undertaking collaboration between the government, industry, and the private sector (for example, clean energy symposiums). The country can build on its experience and expertise to forge technology partnerships with a strategic focus on horizon energy technologies. Technology partnerships should hence be an important element in India's NEP. Such partnerships need not be exclusively for horizon energy technologies. They can also be for acquiring existing technologies that can potentially play a critical role in addressing India's energy needs and challenges.
- Effective technology partnerships could help in bridging the gap between the need for increased investment in energy technologies and the current scenario of low investment in R&D in energy technologies.
- To move ahead strategically on technology partnerships, an institution along with a governing body should be set up to conduct a mapping focused on India-specific needs for technology partnerships along with making descriptive recommendations.
- Funding should be channelised for transforming horizon energy technologies being developed in the laboratory into applicable and marketable forms through technology partnerships.
- For fostering intergovernmental partnerships, the identification of the right stakeholders is critical. India's NEP needs to evaluate the strategic advantages of partnering with different countries.
- A possible option in this regard is the exploration of the possibilities for the transfer and development of horizon energy technologies in India through existing technology-transfer mechanisms (such as the Climate Technology Centre and Network [CTCN]) under the global climate mitigation regime or under bilateral technology transfer initiatives (such as the Joint Crediting Mechanism [JCM] proposed by Japan).

- Generally, technology partnerships are sought to be entered into only with developed nations which possess the required technical and financial capacities. However, there is a tremendous opportunity for India to forge strategic horizon technology partnerships with less developed nations. The capacity of technologically less advanced countries should be appreciated and acknowledged. Their capacity, knowledge, and input should be included in the R&D for energy technologies and appropriate partnerships in the relevant fields should be encouraged. Intellectual property should be protected and should also be used to co-develop and co-own new knowledge.

3.8 Funding is critical, and a high-impact funding pool needs to be created for supporting investments in horizon technology research and partnerships

Funding is required across the value chain, from R&D to commercialisation, for harnessing the strategic potential of horizon technologies in India. The kind of funding, and the type of incentive structure, varies, depending at which stage of the value chain the funding is required. For the current discussion on horizon energy technologies as undertaken at this stakeholder discussion, the focus was mainly on the research and innovation front. The Government of India already extends funding and incentives for many different initiatives across various stages of the value chain. What is required in addition, however, is a strategic funding pool focused solely on horizon energy technologies. This section summarises efforts in this direction in the United States along with the associated financial commitment, and also cites examples from Australia and Germany.

USA

- **ARPA-E:** The Advanced Research Projects Agency-Energy (ARPA-E) is a US government agency that promotes and funds the R&D of advanced energy technologies. ARPA-E started with an initial funding of $400 million in 2009. The budget for subsequent years was increased. It was $180 million in fiscal year 2011 (FY 2011), $275 million in FY 2012, $251 million in FY 2013, and $280 million in both FY 2014 and 2015. Since 2009, ARPA-E has funded over 400 transformative projects across a wide range of research areas, ranging from batteries to biofuels to electricity network integration, and has impressive achievements to its credit.
- **Lithium-ion batteries:** Under the American Recovery and Reinvestment Act of 2009 (ARRA), commonly referred to as the Stimulus Act or the Recovery Act, the United States made a significant investment in building domestic manufacturing capacity and in securing its position as a global leader in the field of advanced lithium-ion battery technology. This investment included:
  - $2.4 billion in loans to three of the world's first EV factories in Tennessee, Delaware, and California.
  - $2 billion in grants to support 30 factories that produce batteries, motors, and other EV components. Companies are matching the funding dollar for dollar, thereby doubling the impact of taxpayer investments. These grants enabled companies to build the capacity to produce 50,000 EV batteries annually by the end of 2011 and 500,000 EV batteries annually by December 2014
  - An innovative approach being considered is the rewarding of communities that invest in EV infrastructure through competitive grants. To provide an incentive for communities to invest in EV infrastructure and to remove regulatory barriers, the President of the United States has proposed

a new initiative that will provide grants to up to 30 communities that are prioritising the deployment of advanced vehicle technology.

- **Solar fuel technology:** In April 2015, the US Department of Energy (DOE) announced up to $75 million in funding to renew the Joint Center for Artificial Photosynthesis (JCAP), a part of DOE's Fuels from Sunlight Energy Hub, which was established in FY 2010 and which is led by the California Institute of Technology in a major partnership with the Lawrence Berkeley National Laboratory, and with the SLAC National Accelerator Laboratory, University of California, Irvine, and the University of California, San Diego, as additional partners. The mission of JCAP is to demonstrate a scalable, manufacturable solar-fuels generator using earth-abundant elements that robustly produces fuel from the sun ten times more efficiently than (current) solar cells . JCAP will receive up to $75 million for an additional five years (subject to congressional appropriations) to continue its foundational research aimed at harnessing solar energy for the production of liquid fuels.
- **Batteries and energy storage:** In 2012, US Secretary of Energy Steven Chu along with Senator Dick Durbin of Illinois, Illinois Governor Pat Quinn, and Chicago Mayor Rahm Emanuel announced funding of $120 million over a period of five years to establish a new Batteries and Energy Storage Hub. The aim of the Hub is to combine the R&D capabilities of five DOE national laboratories, five universities, and four private firms in an effort to make huge advances in battery performance. The Argonne National Laboratory, located outside Chicago, has been chosen to lead the team. Governor Pat Quinn of Illinois allocated $5 million funding for a capital construction plan to help build the state-of-the-art Joint Center for Energy Storage Research (JCESR) facility at the Argonne National Laboratory campus. Additional funding is being considered in future capital funding for the building, which will serve as a nationwide centre for energy storage research. The JCESR facility is a key part of the governor's plan to create jobs and to grow Illinois' economy through cutting-edge innovation.
- **Smart grid:** Since 2010, large public and private investments totalling over $9 billion made under the American Recovery and Reinvestment Act of 2009 (ARRA) have fostered the deployment of smart-grid technology, providing real-world data on technology costs and benefits as well as yielding best practices. The electricity industry spent an estimated total $18 billion for the smart-grid technology deployed in the United States during the four-year period from 2010 to 2013. Smart-grid investments under the ARRA accounted for nearly half of this amount—approximately $8 billion—during the same period. As of December 2015, joint federal and private expenditures under ARRA totalled $8 billion, with the federal share of $3.4 billion, for the 99 projects under the Smart Grid Investment Grant (SGIG) programme, which represent the largest portion of ARRA investments.

Australia

- The Government of Australia initiated the $1.9 billion Carbon Capture and Storage (CCS) Flagships Programme in 2009, administered by the country's Department of Resources, Energy and Tourism, for supporting the construction of two to four commercial-scale CCS projects with a combined capacity of 1,000 GW by 2020. It is part of an expanded $5.1 billion Clean Energy Initiative and complement the Carbon Pollution Reduction Scheme. The programme emerged from the National Low Emissions Coal Initiative, which has been undertaking research, demonstration, mapping, and infrastructure work, and which also includes the Global Carbon Capture and Storage Institute, which was set up by the government to fast-track the development of commercial-scale CCS projects worldwide. The programme aims to fund projects that demonstrate the large-scale use of integrated CCS in Australia and to support widespread national and international use of CCS technology from 2020. Four CCS projects were short-listed for the CCS Flagships Programme funding at the end of 2009:

(1) the Wandoan power project, near Brisbane, Queensland, an Integrated Gasification Combined Cycle (IGCC) coal-fired power station; the ZeroGen project, near Gladstone, Queensland, also an IGCC project; the South West Hub, near Perth, Western Australia, an integrated multi-user capture, transport, and storage infrastructure project; and the CarbonNet project in the Latrobe Valley, Victoria, another integrated multi-user capture, transport, and storage infrastructure project. However, progress on the actual implementation of these projects has been delayed.

Germany

- Energy research has been a strategic element of Germany's energy policy. The responsibility for energy policy is now within the purview of a single ministry, the Federal Ministry for Economic Affairs and Energy. Project funding for basic energy research and bioenergy, however, lies with other ministries. The strategic research domains supported through and by the Federal Ministry for Economic Affairs and Energy are energy efficiency, renewable energy, new grid technologies, and energy storage. The Sixth Energy Research Programme of the German government, which was launched in 2011, has been the vehicle for the promotion of R&D through companies and research establishments for developing innovative energy technologies for tomorrow. Between 2013 and 2016, the German government is committed to providing EUR 3.5 billion in energy research funding to foster R&D of modern energy technologies.
- Hydrogen and fuel cell research has been a critical area of research for the German government. The German government set up the National Organisation for Hydrogen and Fuel Cell Technology (NOW) in 2008 to promote the development and commercialisation of internationally competitive hydrogen and fuel cell technology products. A total budget of EUR 1 billion was committed for hydrogen and fuel cell technology research, development, and demonstration projects over a ten-year period. Of this, EUR 200 million was available as R&D funding, and EUR 500 million was available for the demonstration of hydrogen and fuel cell technologies in the areas of traffic and transport.

4. Policy Recommendation

Setting up of an Expert Committee on Horizon Energy Technologies and Technology Partnerships (EC-HETTP) and establishing a Dedicated Funding Pool

Horizon energy technologies and technology partnerships are central to the discussion on providing 24x7 energy access to Indian households through low-carbon technologies, and simultaneously making India a dominant player in the world energy market. The role of India's NEP is critical in this regard. The policy should lay the foundation for a process that should be institutionalised with the objective of making India a global leader in horizon energy technologies through domestic efforts as well as international technology partnerships.

Based on the outcomes and conclusions of the expert stakeholder discussion coordinated by the Council on Energy, Environment and Water (CEEW), we recommend the creation of an expert committee, to be called the Expert Committee on Horizon Energy Technologies and Technology Partnerships (EC-HETTP), through government mandate. The ultimate goal, post the term of this expert committee, would be the creation of a specialised body to address the issue of horizon energy technologies and technology partnerships on a regular basis so that this process is institutionalised. The EC-HETTP as recommended by the stakeholders could be a first step in this direction. Ideally, this expert committee should be an independent entity having broad representation and should be outside the formal structure of the government, although it should have significant government representation. Being outside the government structure will give the committee the ability to leverage the network of its members, as well as give it flexibility in its functioning and approach, as more and more information is gathered and as more and more avenues need to be explored for achieving the committee's objective. However, coordinating with government ministries, departments, and agencies will be critical to the success of the committee in leveraging expertise within the government, as well as in ensuring that the committee's recommendations have broad acceptance within the government set-up.

4.1 The objectives of the EC-HETTP should be the following:

- Collate and synthesise the existing research findings on horizon energy technologies and technology partnerships both in India and abroad.
- Develop criteria for the identification of horizon energy technologies with a cross-sectoral view, including on-grid technologies, off-grid technologies, and other supply- and demand-side technologies.
- Develop criteria for establishing effective technology partnerships.
- Identify and prioritise a list of horizon energy technologies that are of strategic importance to India based on the identified criteria.

- Review the role, performance, and achievements of the Council of Scientific and Industrial Research (CSIR) in fostering energy technology development and highlight learning and best practices emerging from the efforts of CSIR.
- Propose policies and programmes through which India can move on the path towards the development and commercialisation of horizon energy technologies in an expeditious manner.
- Suggest policies and programmes to enable the formation of high-impact energy technology partnerships at various levels within the country as well as with international organisations and other governments. These could be along the lines of the US DOE's Vehicle Technologies Program,[1] as well as a new Energy Innovation Hub[2] devoted to developing better batteries and increased energy storage capacity to support EVs and other technologies.
- Suggest a plan of action for providing enabling conditions like human resource capacity, finance, networking, etc. for the fulfilment of the objectives of the policy on horizon energy technology development.
- Describe the role of Indian states in this process and detail how government institutions at the state level can participate in the process of horizon technology development.
- Indicate the dedicated annual public funding requirement for the purpose.

The committee should not be prescriptive in terms of its recommendations. Based on all the detailed analyses available so far, this expert committee should ultimately recommend the form, functions, and objectives of a permanent body set up for institutionalising the process of identifying, prioritising, and investing in strategic horizon energy technologies and technology partnerships, for example, the Cell on Strategic Horizon Technologies (C-SHoT). Whether this cell is an autonomous body, or is governed completely by a government ministry or department, is a matter that should be determined by EC-HETTP.

4.2 Process

Within India, there is deep expertise on both horizon energy technologies and technology partnerships. The expert committee should be viewed as a coordinating agency that synthesises and presents this deep expertise from across the broad spectrum of stakeholders. Thus, it is recommended that for addressing each objective, the committee should engage deeply with the stakeholders across all the relevant fields. The process of stakeholder engagement should form the foundation of the work undertaken by the expert committee.

4.3 The Expert Committee on Horizon Energy Technologies and Technology Partnerships (EC-HETTP)should have representation from the following bodies:

- Representative from NITI Aayog
- Representative from the Ministry of Power
- Representative from the Ministry of Coal
- Representative from the Ministry of Oil and Gas

1 http://energy.gov/eere/vehicles/vehicle-technologies-office
2 http://science.energy.gov/bes/research/doe-energy-innovation-hubs/

- Representative from the Ministry of New and Renewable Energy
- Representative from the Ministry of Environment, Forest and Climate Change
- Representative from the Department of Science & Technology (DST), preferably Technology Information, Forecasting, and Assessment Council (TIFAC)
- Representative from the Bureau of Energy Efficiency
- Expert on energy and climate policy research from an Indian think tank with an understanding of policies for promoting horizon technologies
- Academic from a top management institute with expertise on energy and climate policy
- Academic from a top technical institute with expertise in technology development
- Expert from the private sector with expertise in business models related to new technologies, preferably energy technologies
- Expert from a think tank/academia with expertise in technology partnerships

The responsibility for the coordination and management of the Expert Committee should ideally be with a non-government agency.

4.4 A dedicated funding pool and mechanism are required

Path-breaking and transformative research in horizon energy technologies, as well as technology partnerships, can happen only if there is a sustainable pool of public funding available to support it. The experience of other nations, as detailed in section 3.8, shows that countries have earmarked dedicated funds year on year for research on innovative energy technologies and their applications. An important objective of the proposed EC-HETTP should be to suggest the amount of funds that India should start investing regularly for supporting R&D through providing competitive grants to Indian universities and research institutions. Looking at the energy policies, programmes, plans, and goals of the developed countries, India should also think about setting up a dedicated fund to the tune of $ 250 million per year (approximately INR 1,500–1,600 crores) only for R&D. For the demonstration and deployment of technologies, as shown by the CCS experience in Australia and the smart-grid experience in the USA, funding support to the tune of billions of dollars would be required.

Appendix I: List of Participants

LIST OF PARTICIPANTS—STAKEHOLDER ROUNDTABLE DISCUSSION (20 October 2015)		
Horizon Energy Technologies, Technology Partnerships, and the National Energy Policy of India		
Sr. no.	Name	Organisation
1	A. K. Tripathi	Ministry of New and Renewable Energy (MNRE), Govt. of India
2	A. Mohamed Hussain	National Institute of Wind Energy (NIWE), Ministry of New and Renewable Energy (MNRE), Govt. of India
3	Amitabh Shrivastava	CSIR-Tech Private Limited
4	Ankita Sah	Council on Energy, Environment and Water (CEEW)
5	Arumugasamy Gurunathan	Gamesa Wind Turbines Private Limited
6	Arunabha Ghosh	Council on Energy, Environment and Water (CEEW)
7	Biswanath Bishoi	NITI Aayog, Govt. of India
8	Enrico Rubertus	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
9	Harendra Kumar	NITI Aayog, Govt. of India
10	Nanda Kumar Janardhanan	Institute of Global Environmental Strategies (IGES)- South Asia Desk
11	Kalyan Bhaskar	Indian Institute of Management (IIM) -Lucknow
12	Kamanio Chattopadhyay	Indian Institute of Science (IISC)
13	Kangkanika Neog	Council on Energy, Environment and Water (CEEW)
14	Koyel Mandal	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
15	Manoj Kumar Upadhyay	NITI Aayog, Govt. of India
16	Manoj Singh	NITI Aayog, Govt. of India
17	Mridula Dixit Bharadwaj	Centre for Study of Science, Technology & Policy (CSTEP)
18	O. P. Wali	Indian Institute of Foreign Trade (IIFT)
19	O. S. Sastry	National Institute of Solar Energy, Ministry of New and Renewable Energy (MNRE), Govt. of India
20	Poonam Kapur	NITI Aayog, Govt. of India
21	Probal Ghosh	Integrated Research and Action for Development (IRADe)
22	R. K. Kaul	NITI Aayog, Govt. of India
23	Rahul Tongia	Brookings India
24	Rajnath Ram	NITI Aayog, Govt. of India
25	Raman Mehta	Vasudha Foundation
26	Sanjay Bajpai	Technology Mission Division, Department of Science & Technology , Ministry of Science and Technology, Govt. of India
27	Saon Ray	Indian Council for Research on International Economic Relations (ICRIER)
28	Satish Kumar	Lawrence Berkeley National Laboratory
29	Shubha Pandey	Technology Watch & Foresighting (TWF) Department, Department of Science & Technology, Ministry of Science & Technology, Govt. of India
30	Shirish Garud	Energy -Environment Technology Development (EETD), The Energy and Resources Institute (TERI)
31	Srinivas V. Veeravalli	Indian Institute of Technology (IIT) -Delhi
32	Srinivas Rao	AES (India) Private Limited.
33	Surinder Singh Sur	NITI Aayog, Govt. of India

LIST OF PARTICIPANTS—STAKEHOLDER ROUNDTABLE DISCUSSION (20 October 2015)		
Horizon Energy Technologies, Technology Partnerships, and the National Energy Policy of India		
Sr. no.	Name	Organisation
34	Tanikella Chandrasekhar	Technology Information, Forecasting and Assessment Council (TIFAC), Department of Science & Technology (DST), Ministry of Science & Technology, Govt. of India
35	Tribhuvan Kumar Roy	NITI Aayog, Govt. of India
36	Vinod K. Agrawal	ReGen Powertech Pvt Ltd.
37	Vaibhav Chaturvedi	Council on Energy, Environment and Water (CEEW)
38	Winfried Damm	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Appendix II: General Comments on India's National Energy Policy

The stakeholder discussion focused on the issue of horizon energy technologies and technology partnerships. The experts made many comments on general issues related to the NEP. The key comments that will be useful in formulating the NEP have been summarised here.

- The NEP must include key technologies like hybrid technologies within its framework in order to lay down the structure and the rules and regulations for the development of these technologies. It should also scope out the potential of hybrid technology transfer and indicate the regions where solar and wind energy can be co-located.
- A structured policy with a bottom-up approach is needed. It should focus on the relevance of needs in the Indian context.
- Setting up a comprehensive technology management system ranging from use to disposal is important before bringing or introducing any technology in India.
- Building sector energy consumption can potentially corner 30-40% of total energy consumption in India. To cater to this need, we need to develop renewable energy like rooftop solar energy to meet the country's energy demand..
- The role of the private sector and its contribution in bringing about digitisation into the analytics of the system will be important.
- India should have a strategic vision for the development of its energy sources to meet future demand. Investment is required in infrastructure development for incorporating new technologies.
- We need to examine the issue of how India's technology and policy needs are different from those of other countries.
- We need to focus on the creation of a balanced grid because in the future when the supply is likely to be more variable, and notwithstanding the amount of storage available, there will be problems in planning and incentivising.
- The government should ensure that the electricity pricing policy and mechanism are clear and transparent.
- The government should draft a mechanism to pass on the energy savings resulting from taxes on oil or through lower import bills on energy, to the public through tax breaks and to the sectors responsible for the implementation of the technologies.
- Fossil fuel industries need to be involved as stakeholders so as to prevent a loss of interest on their part in the development of the new energy market.
- Government buildings should be converted into low-carbon and energy-efficient buildings. Government officials should be incentivised to adopt EVs.

- New roadmaps that are holistic and integrated compared to the existing ones are required. A well-defined sectoral breakdown of the roadmaps is also required.
- Energy storage systems for the housing sector and for EVs serve different needs. The same is the case with the manufacturing sectors of different technologies, where the roadmap of one energy storage system is not aligned with the roadmap of another sector. Hence, we require new and well-defined road maps.
- The NEP must include thermal energy technologies as these are going to be the mainstay of India's electricity system for some time to come. Transport energy is highly dependent on fossil fuel. The interface between transport and energy is important. The development of CNG-driven locomotives and of biofuel-driven railways are some programmes being pushed by the government. The NEP should focus on clean energy for the transportation sector and on the modal shift of energy.
- Both the previous and the present governments have shown immense interest in pushing the manufacturing and industrial development of the country. The initiatives taken by the present government place emphasis on manufacturing, a policy thrust that has important implications for the future trajectory of India's energy deployment, technological development, innovation, and the NEP.
- Rules and regulations in terms of general financial rules, income tax law, etc. that discourage joint ventures should be reviewed and revised, if required.
- The manufacturing and adoption of EVs is essential for bringing low-carbon technologies into the transport sector., Both the government and industry need to push in order to strengthen the policy for the promotion of EVs in India. Charging infrastructure for EVs will become more widely available only when there are enough electrically operated vehicles on the road, and the sale of EVs will only rise when the facility to charge these vehicles is readily available in the market.
- In relation to the National Electric Mobility Mission Plan (NEMMP 2020), which was launched in 2013, the challenge is to provide an extensive, robust, and reliable charging infrastructure for EVs, given the target of 67 million EVs by 2030 (mainly electric scooters). This would require at least 2 GW additional power for meeting the charging demand of the EVs sector.
- The installation of charging stations is a low-cost infrastructural facility, does not require high R&D costs, and can be supported by urban local bodies. For example, Beijing has installed 10,000 charging stations to enhance the technology uptake in the market, providing citizens with ready infrastructure.
- Issues like the time required for charging, the dispatch strategy, and the role of the smart grid will be important in the long term beyond 2030.
- The government (Department of Heavy Industry, Ministry of Heavy Industries & Public Enterprises), in consortium with industry and academia, has identified four different areas to conduct R&D to support electric mobility—vehicle system integration, chargeable energy storage system, power electronics, and charging infrastructure. The government has also developed specifications and standards in all the areas and has recommended addressing the challenges through the formation of consortiums.

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