protocols respectively. Blockchains use the proof of work concept to add new blocks, which in turn fetch an incentive to people who add blocks.

In blockchains cryptographic primitives such as hash functions and public key cryptography are required to achieve anonymity, authenticity and secrecy. These concepts were explained by Bimal Roy (ISI, Kolkata). Hash functions ensure the properties of one-wayness, second pre-image resistance and collision resistance. Public key cryptography achieves the function of authentication.

The economic aspects of bitcoin were explained by S. P. Suresh (CMI, Chennai). Bitcoin is an infinitely divisible digital currency that can be used to trade for goods/services or can be exchanged for other forms of currency. The bitcoin algorithm based on block chain technology that runs on all nodes in a peer to peer network, generates bitcoins. According to the monetary policy of the algorithm, 21 million bitcoins will all be minted by 2148 after which the minting stops. Since there is no central authority to decide on factors such as money supply, etc., any changes in the system are carried out democratically. It is truly international since anybody with internet access can transact in bitcoins without having to submit to the laws of the particular region. He also explained the technical aspects of bitcoin generation and incentive structures in bitcoin.

Rajeeva L. Karandikar (CMI, Chennai) concluded the symposium by providing the use of blockchains beyond cryptocurrency. The basic premise is that distributed copies are difficult to tamper with. Blockchain technology can be used in applications such as logistics/shipping, land and property records, etc. However these applications have several unanswered questions such as acceptability to the people owing to lack of a central authority and incentive structures in areas such as land records.

The event concluded with a second special lecture by Raman Sukumar (IISc, Bengaluru), who provided a perspective of long-term thinking in ecology that was substantiated by insights from long-term monitoring of a tropical forest in Mudumalai. This research is especially relevant in the context of global climate change.

The Western Ghats show enormous variation in rainfall across the gradient. Correspondingly there is a change in the type of vegetation from dry thorny forest to dry deciduous forest to moist deciduous forest to patches of evergreen forests as we move west. Sukumar and his team set up a 50-ha permanent plot in the dry-deciduous forest of Mudumalai in 1988. Since this represented only one point in the rainfall gradient, 19, one-hectare plots were also set up along the rainfall gradient. The fate of over 80,000 individuals from nearly 200 species was monitored by the team over three decades. The long-term monitoring of the forest provided crucial information on population trends, mortality and recruitment, growth, survival and diversity of species owing to factors such as fire, rainfall, etc.

Sukumar indicated that the monitoring has also provided new insights into the theoretical aspects. The autecological/individualistic theory was favoured by the work carried out in Mudumalai. Also, looking at different forests around the world, data supported the fact that environmental stochasticity overrides both niche and neutral considerations in driving the dynamics of the forest.

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MEETING REPORT

Techno-foresight in R&D*

In this era of rapid technological developments, new approaches are necessary to stay relevant and competitive; the global industry is becoming more and more science and technology (S&T)-centric. The future industry is expected to be driven by S&T-enabled products and innovations. However, S&T products need large investments and long development timescales. Techno-foresight is the process of anticipating the broad contours of technologies to come. It can also help in overall policy planning; unlike techno-foresight for a specific product, techno-foresight in policy can be used to ensure inclusive economic growth through development of the complete industrial ecosystem. It is an emerging area, enabled by the recent advances in data analytics, modelling and simulation.

Techno-foresight is going to play increasingly important roles in industrial and R&D investment planning. The methodologies as well as applications are going to evolve and expand. There is need for an institutional effort for the development and upgradation of methodologies, applications and capacity-building. Also, carefully developed techno-foresight practices can be vital for agencies like the Council of Scientific and Industrial Research (CSIR) engaged in S&T-driven industrial research.

Techno-foresight encompasses a broad range of goals and a wide spectrum of methodologies. Technology Visions are regularly generated by agencies like DST aimed at broad national agenda. However, there is need for focused and systematic applications of techno-foresight in R&D aimed at industrial products. The First National Workshop on Techno-Foresight and R&D Investment Planning was aimed to create an effective techno-foresight platform by integrating modern techniques and emerging demands, covering recent advances and future directions in data analytics, projection and simulation methodologies to make techno-foresight an applicable tool for the industry. The participants included experts as well as thought leaders; the event was structured in terms of sessions to cover both basic issues, techniques and applications of techno-foresight in S&T-driven R&D.

Internationally, techno-foresight is fast emerging as an important science. Many

*A report on the first National Workshop on Techno-Foresight in R&D and Industrial Investment Planning held at CSIR-NISTADS, New Delhi on 11 October 2017.

countries have adopted it as a regular component of their R&D investment planning; countries like Japan and South Korea have institutes dedicated to techno-foresight. It is emerging as a key component of industrial investment planning, to develop client-demand profiles for technology-demand scenarios several years ahead. As India makes a transition from supply and distribution-centric industries to production-based industries through initiatives like Make-in-India, practices like techno-foresight will become increasingly relevant and critical. This is also an era of rapid S&T innovations; products become obsolete in a relatively short time.

For India, tools like techno-foresight can play a critical and enabling role by ensuring relevance and competitiveness of technologies developed at the time of their entry into the market. However, techno-foresight is still a relatively new practice in our country, especially in the public sector. Science issues include algorithmic description of techno-foresight in terms of parameters like

- Time of emergence and market relevance.
- Time of stabilization.
- Socio-economic implications.
- Dynamics of technology, risk-benefit modelling, decision system (uncertainty management scenario building).

Application of techno-foresight can result in reduction in design cycles and product profiling. However, some of the major challenges in the application of techno-foresight are decision amidst deep uncertainties.

Unlike techno-foresight for a specific product, techno-foresight in policy can be used to ensure inclusive economic growth through development of the complete industrial ecosystem. Techno-foresight is potentially useful in many sectors, especially where developments in S&T have a strong bearing in the product profiles and market demands. However, as techno-foresight is a relatively new practice in India, this workshop was aimed at bringing together experts from different disciplines involving techno-analysis from academia, R&D organizations and industry.

In his overview of the workshop, P. Goswami (NISTADS, New Delhi) emphasized the importance of technology foresight to develop S&T-enabled products which will definitely be the future need of most industries. He highlighted the benefits of technology foresight in planning investment decision for developing the S&T-enabled products that take several years for maturing.

Emphasizing the need to be globally competitive in industry, Girish Sahni (CSIR, New Delhi) stressed the need to incorporate modern techniques like techno-foresight into the project planning cycle. Highlighting the critical and the enabling roles S&T has to play in sustainable development, he emphasized the need to integrate parameters like return-on-investment into R&D planning.

Techno-foresight should not only be pursued as a technique, but also at a conceptual level. V. K. Saraswat (NITI Aayog, New Delhi) stressed that the foremost objective was to understand the relevance of the various technologies that have been developed by various organizations. He stressed the need for policy research institutes like NISTADS, to work towards developing scientific quantitative techniques and tools for techno-foresight. Saraswat also stressed that techno-foresight must also be reflected in the curriculum so that it can be implemented from the grassroot level.

The workshop then proceeded with its various technical sessions.

P. S. Goel (NIAS, Bengaluru), chairing the first technical session, emphasized the scope and need for closing the gap between techno-foresight and investment planning. He emphasized that the technology developments in research laboratories are not reaching the logical goal of market entry; due consideration of the relevant socio-economic factors and techno-foresight should be integral parts of our research and development plans.

P. Desai (JNU, New Delhi) discussed about various trends and approaches in techno-foresight. He emphasized that techno-foresight was more than simple predictions. He also emphasized the need for ensuring wider public participation in developing techno-foresight, involving students and common people to understand the broader demands from technology.

R. K. Sinha (CSIR-Central Scientific Instruments Organisation (CSIO), Chandigarh) stressed the need to address important procedural issues like whether techno-foresight should be implemented in one place or in each laboratory separately.

The question of assessing risks in techno-foresight was raised by Neelash (CSIR-CSIO). It was appreciated that techno-foresight would have associated uncertainties and thus risks. However, it can still be useful to prioritize research and associated investment. Mohd Rais (CSIR-NISTADS) brought out the challenges in resource planning/utilization for 30 years. For different perspectives, the priorities are different. We cannot be rigid about any planning and thinking for techno-foresight. Based on the situation, there will be a need to take relevant action. Sujit Bhattacharya (CSIR-NISTADS) highlighted the procedural complexities involved in the implementation of techno-foresight. It was felt that uniform procedures should be devised.

A number of major recommendations emerged from the panel discussions. These include:

(a) A systematic application of techno-foresight in planning and design of R&D and industrial investment to enhance relevance and applicability of S&T products for competitiveness of Indian industry.

(b) A roadmap for practice of techno-foresight in R&D planning in India.

(c) Systematic development and applications of techno-foresight methodologies and tools.

(d) Periodic and systematic techno-foresights in different sectors.

The workshop strongly recognized that application of techno-foresight would result in knowledge infusion to planning in S&T for industrial relevance and competitiveness. At longer timescales, systematic techno-foresights can help technology leapfrogging through knowledge-based planning for next-generation technologies.

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