Technologies for Sustainable Development: Korean Experience

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Introduction

The World Commission on Environment and Development (WCED)'s report in 1987 is viewed as a major political turning point for evolution of the concept of sustainable development (Mebratu 1998). Since then, the influence of the concept has increased extensively, and it features more and more as a core element in policy documents of governments and international agencies (Mebratu 1998).

The concept of sustainability and sustainable development may be understood intuitively, but it remains difficult to express in concrete, operational terms (Briassoulis 2001). However, many agree that sustainable development is about achieving environmental, economic, and social welfare for present as well as future generations (Azapagic and Perdan 2000). From governmental perspective, this can be at national and global levels (UNCSD 2001). From an organizational perspective, this can be at project (Labuschagne et al. 2005) and technology (Brent et al. 2005, 2006, 2007) levels. Sustainable development has subsequently been conceptualized as a state of dynamic equilibrium between societal demand for a preferred development path and the supply of environmental and economic goods and services needed to meet this demand (Briassoulis 2001).

Consensus on the general objectives and basic principles of sustainable development may be obtained in theory. But consensus on the details of how to achieve sustainable development or maintain sustainability is difficult to obtain in practice. This difficulty can be attributed to the variety of perceptions on specific sociocultural and political contexts that change over time (Briassoulis 2001; Brent et al. 2005).

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Sustainable Development and Globalization

Globalization and sustainable development is at the top of today's international agenda, covering a wide range of issues, such as, inter alia, trade, development, environment, resources management, development cooperation, and international governance. The basic understanding of "sustainable development" derives from the 1987 UN World Commission on Environment and Development report, entitled "Our Common Future," as "a development that meets the needs of the present, without compromising the ability of future generations to meet their needs." The report also established that this requirement applies not only to environmental policies but also to economic and social policies as well (Lucas 2004).

Sustainable development is a multidisciplinary process that involves all issues, such as science, innovation, technology, R&D, information technology, e-commerce, economic development, health, foreign direct investment, multinational companies, international debt, and related issues (Ahmed and Stein 2004; Stein 2002).

Sustainable development is based on three pillars: the environment, the economy, and the society. The framework domain for sustainable development should take into account a set of parameters which determine the feasibility of the model for direct beneficiaries, non-beneficiaries, national values, the environment, and the stability of the system. Broadly, sustainability can be defined with the constituents such as:

(a) Economic sustainability
(b) Technological sustainability
(c) Social sustainability
(d) Environmental sustainability
(e) Value sustainability (Abdul Kalam and Singh 2011)

On the other hand, "globalization" refers to the growing integration of the global economy, which is being brought about by incessant flows of goods and services, capital, technology, and information across national borders. In its wider sense, globalization is not only about economic processes; it also covers the increasing cross-border contacts in other spheres, including the exchange of ideas, knowledge, and cultural manifestations. Globalization is, first and foremost, a continuation of the historical process of internationalization, which has increased the economic, social, environmental, and political interdependence of countries (Lucas 2004).

An outcome of globalization is that the international cooperation in science and technology from small cross-border research projects to global-scale coordination must be considered as a key tool for enhancing sustainable technological development in key areas, such as water, energy, health, and education. Thus, there is both a need and a scope for regional and global cooperation in sustainable development. Mechanisms must be put in place to facilitate such international exchange of domestic and global experiences in sustainable development.

Sustainable Development: Dimensions and Areas

There is an inherent linkage (Kates Robert et al. 2005) between "what is to be sustained" and "what is to be developed." While "what is to be sustained" deals with:

(a) Nature (earth, biodiversity, and ecosystems)
(b) Life support (ecosystem, services, resources, environment)
(c) Community (cultures, groups, and places)

"What is to be developed" relates to:

(a) People (child survival, life expectancy, education, equity, equal opportunity)
(b) Economy (wealth, productive sectors, consumption)
(c) Society (institutions, social capital, states, regions)

Thus, the dimensions for sustainable development are primarily based on three pillars, each of them covering certain areas. They are as follows.

Dimension	Areas
Environment	Climate, water, biodiversity, natural resources, etc.
Economy	Jobs, wealth creation, investments, energies, etc.
Social aspect	Education, health, standard of living, etc.

Energy, water, education, and environment are essential to every aspect of life for social equity, ecosystem integrity, and economic sustainability. It affects all aspects of development—social, economic, and environmental—including livelihoods, agricultural productivity, and health.

To develop technologies for some of the above areas under the three dimensions, right type of innovation ecosystem should be established.

Innovation Ecosystem for Technology Development

An innovation ecosystem consists of economic agents and economic relations, as well as the noneconomic parts such as technology, institutions, sociological interactions, and the culture. Deborah Jackson (Debora Jackson 2011) describes a model of innovation ecosystem based on two distinct, but largely separated, economies: the research economy, which is driven by fundamental research, and the commercial economy, which is driven by the marketplace (Fig. 1).

This model links the innovation spectrum to the two economies in the virtuous cycle, thereby illustrating the projection, along the different development stages, of the available resources within an ecosystem for discovery, technology development, and commercialization. An important feature of a sustainable innovation ecosystem is that the resources available to the research economy are coupled to the resources generated by the commercial economy, usually as some fraction of the profits in the

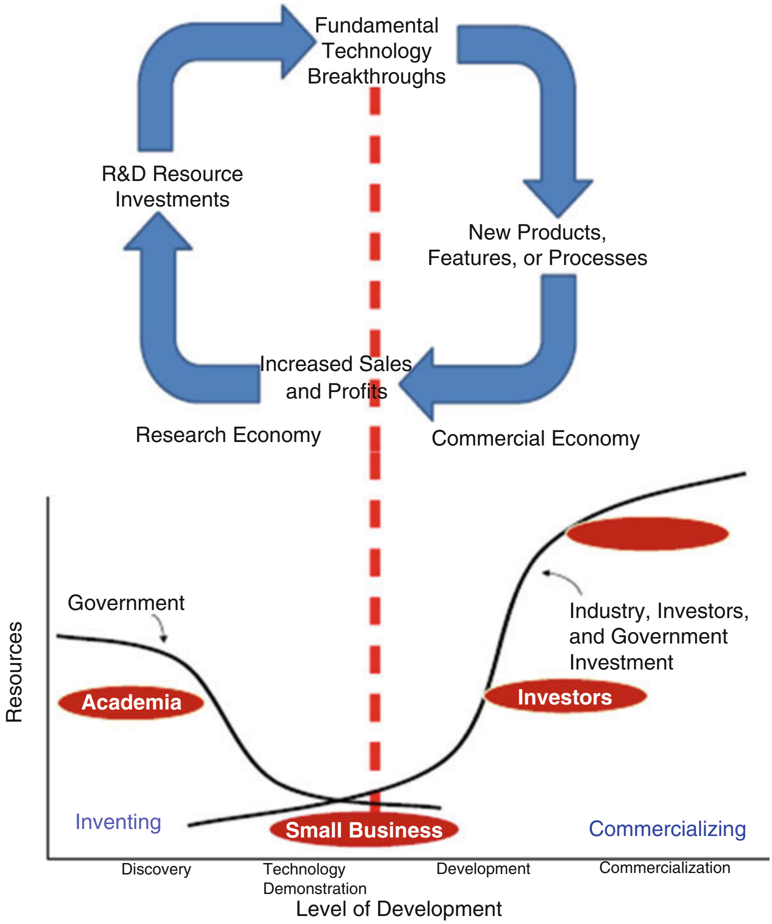

Fig. 1 Ecosystem for discovery, technology development, and commercialization (Adapted from Deborah Jackson 2011)

commercial economy. An innovation ecosystem is healthy and sustainable when the two economies (research and commercial) exist in balanced equilibrium. The challenge to creating growth in an innovation ecosystem is to figure out how to turn the breakthroughs of basic and fundamental research efforts into products that lead to profits. Achieving this goal is complicated by the fact that the two economies operate on different reward systems, thereby making it challenging to link discoveries derived from fundamental research with innovative products that can translate into profits in the marketplace.

Henry Etzkowitz (Henry Etzkowitz 2007; Henry Etzkowitz et al. 2007) has extensively worked on innovation ecosystem based on triple-helix model of innovation and university–industry–government interaction. The triple-helix model is composed of three institutional spheres, viz., university, industry, and government interacting closely while each maintaining its independent identity. In this model, universities, industry, and government assume some of the capabilities of the other, as each maintains its role and distinct identity. The triple-helix model attempts to capture this transformation of roles and relationships among these spheres. There is a shift from typical bilateral interactions (university–government, university–industry, and government–industry) to trilateral interactions among these spheres through increased role taking. Triple helix is an interactive model and consists of overlapping, yet relatively independent, institutional spheres. For example, academia plays a role as a source of firm-formation and regional development in addition to its traditional role as a provider of trained persons and basic knowledge. Government helps to support the new developments through changes in the regulatory environment, tax incentives, and provision of public venture capital. Industry takes the role of the university in developing, training, and research, often at the same high level as universities. Many countries and regions are presently trying to attain some form of triple helix, with university spin-off firms, trilateral initiatives for knowledge-based economic development, and strategic alliances among firms (large and small, operating in different areas and with different levels of technology), government laboratories, and academic research groups.

Korean Technologies for Sustainable Development Areas

Indo–Korea Science and Technology (IKST) Center, a section 25 company established by KIST, provides a platform to showcase some of the successful relevant technologies that are outcome of systematic scientific research done by research institutes in Korea. These technologies have high potential to address some of the developmental issues in the Indian rural context, and these can be applied through appropriate localization process and sustained through community involvement.

Water Purifier Technology

Clean drinking water is a global problem. Globally more than one billion people lack access to safe drinking water, and India has significant share of this deprived population. India faces an enormous challenge in providing its citizens with clean potable water free from pathogenic bacteria, viruses, and cysts which cause diseases such as diarrhea, cholera, typhoid, and amoebiasis. Moreover, due to overexploitation of ground water, the levels of mineral contaminants such as arsenic and fluoride in water drawn from wells have increased dramatically. In rural India, about 75% of the population does not have access to safe drinking water. Hence, clean water for all is a very important societal mission where the scientific community and the industry have to find synergies (Amrit Pal Singh 2010; Abdul Kalam and Singh 2011).

The solutions for clean water are assessed on the following parameters (Abdul Kalam 2011);

- Core technology used and its efficacy in removing the organic, inorganic, and microbes present
- Its cost effectiveness, both in terms of fixed and operational costs
- Ease of use, mobility, and adaptability
- Capacity of water cleaning and maintenance requirements
- Environmental impact
- Its dependence of the other aspects like availability of power and running source of water and the potential solutions

Water purifier technology that has been developed by Korea Institute of Science and Technology (KIST) is basically a low-cost water purification system which ensures all the above-mentioned assessment parameters are addressed effectively. The purification system houses five filters in a compact casing and provides five-step filtration process. This technology completely kills and removes microorganisms, removes solid materials such as iron oxide and sand, absorbs soluble chemicals, and also improves the taste of water. It has very low maintenance cost. This technology could be a very good solution to address bottom of pyramid market.

Sewage and Wastewater Treatment Technology

Conventionally, sewage is collected through a vast network of sewerage systems and transported to a centralized treatment plant, which is resource intensive. Instead of transporting it long distance for centralized treatment, the Central Pollution Control Board is promoting decentralized treatment at the local level using technology based on natural processes. After proper treatment, sewage can be used in pisciculture, irrigation, forestry, and horticulture (Kamyotra and Bhardwaj 2011).

Water Environment Center at KIST has developed wastewater treatment and recycling system technology for treatment of various types of sewage and industrial wastewater using microorganisms. Biological wastewater treatment involves the use of microorganisms (bacteria) to naturally degrade organic waste resulting in biochemical oxygen demand (BOD) and chemical oxygen demand (COD) reduction and wastewater odor control. Wastewater should be treated on site, at local places (decentralized), for example, in restaurants or households, rather than at many wastewater treatment plants. It is an environmentally friendly, relatively simple, and cost-effective alternative to chemical cleanup option. This is an advanced treatment technology. It is composed of an anaerobic tank, an aeration tank, a contact aeration tank and a sediment tank. It removes organic matters by maintaining microorganism concentration in the aeration tank and activating microorganisms in the microorganism controlling tank continuously. It also reduces the bad smell. The treated water can be directly reused (agricultural water, wastewater reclamation, and reuse system), and the dehydrated sludge can be used as compost.

ICT and Robotics in Rural Education

The emergence and convergence of various Information and Communication Technologies (ICT) such as computers, Internet, and multimedia provide unique opportunities for promoting primary and secondary education, on a mass scale, in developing nations like India. There is a general consensus among practitioners and academics that in diverse socioeconomic and cultural contexts ICTs can be successfully employed to reach out to a greater number of students and help in promoting learning and knowledge.

Due to the rapid developments of new technologies, educational researchers can now apply various ICT tools in practical scenarios to enhance learning experiences and performances of learners such as multimedia and robot. Backed by its strong IT environment and advances in robot technology, Korea has developed the world's first e-learning robot. This has demonstrated the potential for robots to be used as a new educational media. Robot technology is expected to become more interactive and user-friendly than computers in the near future. Also, robots can exhibit various forms of communication such as gestures, motions, and facial expressions (Han et al. 2008).

In February 2010, Ministry of Education in South Korea announced that they will equip robots for all 8,400 domestic kindergartens to facilitate instruction by 2013. Educational researchers have shown that the robot as an instructional assistant or as a learning companion can enhance learners' learning motivation and learning performance. Furthermore, using robot as an instructional assistant or a learning companion can also enable instructors to provide learning content which facilitates learners to interact with real objects through navigating digital learning content. For example, while learners are learning physics, the robot can utilize its capabilities, including rotation, mobility, and acceleration, to explain the Newton's laws of motion (Chun-Wang et al. 2011).

KIST has been focusing on the development of intelligent robots and fundamental technologies for robots during last two decades. They have been working on technologies to provide human-friendly services for human beings by combining intelligence technologies and biomimetic sensing-and-control technologies with traditional robot technologies, for example, robots for English teaching, elder care, teaching science, education for disabled/autistic children, edutainment, information services, and home service.

Plasma-Enhanced Integrated Gasification Combined Cycle (PE-IGCC) Technology

The technology under discussion is "Plasma-Enhanced Integrated Gasification Combined Cycle (PE-IGCC)—Electricity Generation Power Plant" using Indian run-of-mine coals having high ash content. This technology can be utilized for small-scale distributed power generation plants in the range of 500–2,000 KW providing electricity in remote villages where grid power is not feasible or not cost-effective. This technology provides a good alternative solution to other types of Decentralized Distributed Generation (DDG) systems based on biomass, solar PV, etc.

Basically, an IGCC-based power plant using coal is a technology that turns coal into gas—called syngas. It then removes impurities from the gas before it is combusted. The electricity is generated using a combined cycle, consisting of three stages:

1. A gas turbine generator that burns the syngas.
2. Heat from the gasification and the exhaust heat from the gas turbine are used to create steam.
3. Then the steam is used to power a steam turbine generator.

Though the IGCC technology is less polluting than conventional coal-fired power plants, it generally requires coal with low ash content of up to 10 %. Although India has a very large reserve of both coking and noncoking coal, the quality of Indian coal is poor due to very high ash content. Typically Indian run-of-mine coals have high ash content (ranging from 40 to 50%), high moisture content (4–20%), low sulfur content (0.2–0.7%), and low calorific values (between 2,500 and 5,000 kcal/kg). Hence, PE-IGCC technology (currently under development) which can make use of low-grade Indian coal could be an excellent alternative to the other existing technologies such as solar, wind, and biomass for rural electrification in India. Typically, existing IGCC technology utilizes high-quality coal (>7,000 Kcal) and high moisture (4–12%) and low lime content (<12%) with high-energy capacity. However, it is possible to use the low-quality coal with 45% lime material for PE-IGCC technology. This technology under discussion is basically a pure steam–plasma torch generated by microwave energy and uses it for gasification of low-grade coal in a compact and lightweight operating system. The high temperature of the steam torch when used for fast gasification reactions of low-grade coal ensures a compact reaction system.

With the largest rural population in the world, India is facing a huge electrification challenge. Today, 64.5% of India is electrified, with an electrification rate of 93.1% in urban settings but only 52.5% in rural areas. This technology once developed will be highly suited for rural India.

Solar Lighting System

The technology under discussion is a high-powered LED-based solar lighting system which could be used for highways, villages, etc. The uniqueness of this system is:

- High powered—60 W
- Communication interface for remote operation
- Tracking of sunlight for maximum efficiency

This technology could be localized for Indian condition considering the cost and wattage specification for various solar PV applications.

From the point of view of rural and remote area electrification, the scope for renewable energy is immense. India has significant potential for generation of power from renewable energy sources such as wind, small hydro, biomass, and solar energy. Special emphasis has, therefore, been given to the generation of grid quality power from renewable sources of energy.

According to National Solar Mission target, off-grid solar PV products/systems would contribute 2,000 MW by the end of 2022. The most of which is to come from solar lighting systems—solar lantern, home light, and solar street light for both rural and urban. National Solar Mission also plans to deploy 20 million solar lighting systems for rural areas by 2022 (National Solar Mission, MNRE).

Education–Enterprise Framework for Emerging Economics

Implementation and management of these technologies require a right framework that shall take in to account requirements of all the stakeholders, resources availability, operational environment, and communication requirements.

The education–enterprise (E–E) model (Biswas et al. 2010; Saurabh 2009; Saurabh et al. 2011) is a special adaptation for BASIC (Brazil, South Africa, India, and China) and emerging economies of the conventional triple-helix model for providing the collaborative framework among academia, government, and the private enterprise focused toward creating social entrepreneurship driven enterprises. E–E model is a diversion from the triple-helix model and hinges more on the mutual interaction of the E–E model with government as a partner. As per E–E model, the needs of the society have been identified under four basic pillars of the society under the education, environment, energy, and health (EEEH) with all of them having equal roles to play in the societal development. Most of the basic needs could be satisfied if entrepreneurs could cater to the needs under the EEEH (education, energy, environment, and health) domain (Fig. 2).

In this framework, the education and enterprise overlap to spin-off social enterprises to improve the social conditions, especially in the emerging/BASIC nations. The government is very much part of the collaboration, but in a noninterfering manner which means that it allows for all necessary infrastructures, monetary, and moral support without interfering in its working. Thus, the model caters to the policy of decentralized power in the hands of the academia (which hosts the program and provides manpower and administrative support) and the industry (which provides the expertise to engage the project). The government role is restricted to monitoring the funding and its utilization. The academia which provides the base for sustenance through knowledge creation under the EEEH framework creates entrepreneurs by using the faculties to train students to become entrepreneurs and innovators. The industry which benefits by getting consultancy and IP generation through innovations coming out of the academia allows the statist BASIC country

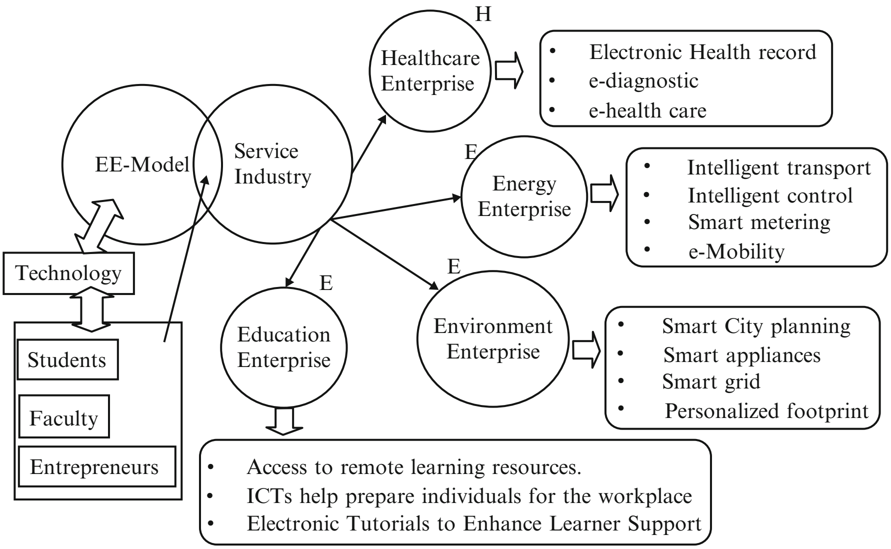

Fig. 2 The co-entrepreneurship model emerging from E–E model (Biswas et al. 2010; Saurabh 2009)

governments to bring in the resources allowing the university campus to be in total free market mode, interacting with private enterprise with a judicious mix of enterprising students and motivated local entrepreneurs. While this will allow invigoration of existing business model involving local people for intense local problems, it will also lead to creation of whole new industry in cluster around the campus. Enterprises in the domain of energy, environment, education, and health help find sustainable solutions to local problems based within the EEEH. Such enterprises will bring in rapid business formation leading to adequate social profit motives in addition to meeting the monetary objectives.

Korean Experience in Technology Development and Management

A spiral process model of technological innovation in developing countries is reviewed by Ali and Park (2011). This can as well apply to developed countries. Any technological innovation cycle passes through four stages: (1) technological innovation (TI), (2) transfer of technology (imitation), (3) adaptive technological innovation (improvement), and finally (4) indigenous technological innovation (local innovation). The development of technological innovation is a cyclic process.

Science, technology, and innovation have been cited as one of the key factors behind the economic success of South Korea. By making continuous and massive investments in research and development and in innovation, Korea has succeeded in building a unique innovation system that supports sustainable growth of the Korean economy. The development of innovation and R&D system of South Korea can be classified under three main processes: imitation process (1960s and 1970s), transformation process (1980s), and innovation process (1990s onward) (Arslanhan and Kurtsal 2010; Sung Chul Chung 2011).

During the innovation process phase, Korean government, along with the Asian crisis that became visible particularly by the second half of 1990s, felt the urge to shift technology policies from large industrial firms prioritized until then to relatively more flexible, dynamic, and innovative SMEs, small-scale R&D centers, and technology-based small firms. Korea's technological competitiveness in semiconductors, displays, cellular phones, computers, telecommunications equipment, and so on is partly the result of the government–industry collaborative R&D.

In recent years and getting halfway through the innovation process, policies targeting to increase basic research have gained ground with the aim to establish an integrated innovation system and secure sustainable economic growth. Recently, with its commitment to the innovation policy, sustainable development, and knowledge-based economy, Korea initiated the creation of the *International Science and Business Belt* (ISBB) to bolster its capacities in the basic and fundamental science areas through the establishment of the Basic Science Institute. One of the objectives of this belt is to lay the business foundation for the sustainable and urban growth. The aim is to foster a business environment to attract global enterprises focusing on R&D in nanotechnology, biotechnology, information technology, and green technology, so that their research can be linked to the basic science research and create a synergy effect facilitating convergence between scenic and businesses (Twa Netwark 2011).

Conclusions

Sustainable development is of utmost concern to the global society today. Though it has often focused on environmental concerns, sustainable development has three dimensions: economic, environmental, and social. The sustainable development requires fundamental changes in the way of growth and development process happening in the world. Industries should develop their business model not only based on economic performance but also taking account of the environment and social impacts. Governments should adopt legislation and regulation on economic activities and environmental issues to enhance sustainability consideration and social awareness. Innovation is an essential driver for sustainable development. There is need for an innovation ecosystem and framework comprising all public and private sector stakeholders interacting closely with surrounding environment rather than a linear model of innovation (basic research) and thereafter technology development (applied research) which gets embedded in useful products and services. The increased interaction among university, industry, and government as relatively equal partners is the core of economic and social development. The linkage between university/research institutes and industry plays an important role for making the ecosystem sustainable and making the society more innovative.

Universities and research institutions in Korea and India have already developed certain technologies in the core areas like energy, drinking water, clean environment, health, and education. However, establishing suitable linkage mechanism between universities/research institutions and industries/investors through appropriate policy interventions and programs will play a key role in realizing the goals of sustainable development.

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