# Innovation and Technology for Green Growth

**Nathan Hultman,** Associate Director, Joint Global Change Research Institute, University of Maryland; Non-Resident Fellow, Global Economy and Development, Brookings Institution

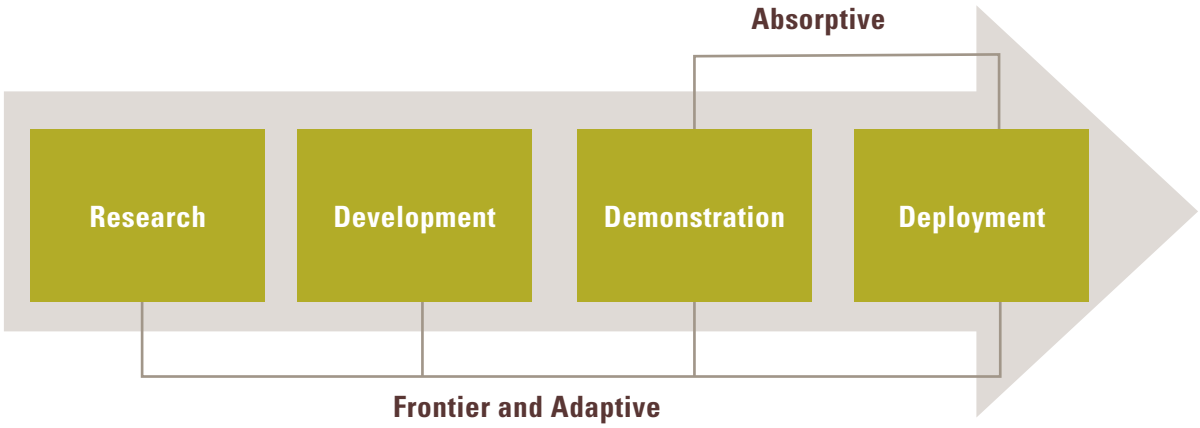
**Katherine Sierra,** Senior Fellow, Global Economy and Development, Brookings Institution

**Allison Shapiro,** Fellow, Erb Institute for Global Sustainable Enterprise, University of Michigan

**For many years, the international community has approached environment and development challenges through the lens of sustainable development—usually conceived as meeting the needs of the current generation while not sacrificing the ability of future generations to meet their own needs. Though this approach has been constructive and successful in many ways, it lacks a clear pathway for how to realize those goals. As just one of many examples, addressing climate change will require fundamental transformations to the energy system, which the International Energy Agency estimates could demand up to $46 trillion of additional investment by 2050;[1] and more than three-quarters of the total new energy investment will be directed to developing countries. This capital will not come from government development efforts, but instead must be leveraged through new markets, new business models and new policies.**

"Green growth" seeks to establish pathways for sustainable development through a combination of private sector innovation and engagement within a supportive national and international policy context. It aspires to tackle three challenges simultaneously: encouraging development and poverty reduction; creating new and more vibrant economies based on clean technologies; and securing an increasingly greener world. Of course, tackling such challenges as climate change, energy access, environmental degradation, sanitation and water availability while achieving economic and development goals will require unusually creative approaches based on new and profitable business models, novel approaches to financing and innovation in both U.S. and global institutions. Though not sufficient in isolation, green growth innovation will enable the advances toward goals in human health, natural resource sustainability and social equity. Countries can also benefit from cultivating new green industries as a matter of domestic economic policy. Innovations in green technology therefore represent potentially

**FIGURE 1. TYPES OF INNOVATION ACCORDING TO THE PHASE OF TECHNOLOGY DEVELOPMENT**




*Source: Brookings.*

transformational approaches to some of the world's thorniest development and environment challenges—but realizing that potential will require creative approaches for vibrant private sector engagement.

## WHAT IS GREEN GROWTH INNOVATION?

As a result of more widespread economic development in recent decades, global capacity for research and development is evolving broadly across the developed world and emerging economies. However, building on this progress will require action to encourage new ideas across the diversity of development contexts, and to ensure that these ideas can reach and transform new markets. The challenge of transitioning onto cleaner development pathways is particularly difficult for developing countries because their need for rapid economic growth often seems to outweigh the importance of "leapfrogging" onto cleaner development trajectories. Achieving sustainable economic development will require regional and international cooperation for implementation, supportive domestic policies, institutional capacity building, strong public–private partnerships, long-term financing and human capital development. In parallel, new mechanisms are needed to support the development and diffusion of intellectual property that can be shared with, and created in, developing countries along with enforcement mechanisms for its protection. Many existing initiatives have been launched to support this goal, but they have not achieved scale nor are they expanding at a rate sufficient to tackle the challenges.

Innovation for green growth can be characterized as frontier, adaptive or absorptive (see figure 1). *Frontier innovations* are novel solutions that have not yet been introduced to the world. They are typically adopted in the research phase of the technology development cycle. *Adaptive innovations* are modifications to existing technology that make them more useful in alternative situations. They can occur across the technology development cycle. *Absorptive innovation* refers to changes to an institutional environment that makes the transfer, successful implementation of, and learning from frontier and adaptive innovations easier. This applies to the final two stages of the development cycle. Examples of this type of innovation include in-country infrastructure for knowledge and device diffusion, regulations to support intellectual property (IP) protection, and international agreements for technology transfer (for examples of green growth initiatives, see box 1).

When the term "innovation" is applied to technological change, it is often conceived of as a change to a product or service—for example, a higher-yielding seed or a more efficient delivery system—but it can also describe improvements in business models or a process change. When applied to a process change, however,

## BOX 1. EXAMPLES OF GREEN GROWTH INITIATIVES IN DEVELOPING COUNTRIES

*Sustainable Energy for All:* An initiative launched by U.N. secretary-general Ban Ki-moon in 2012 ahead of the Rio Earth Summit, with the goal of mobilizing actors across a broad spectrum for urgent action to achieve three objectives by 2030:

- Ensure universal action to modern energy services.
- Double the rate of improvement in energy efficiency.
- Double the share of renewable energy in the global energy mix.

Although the initiative did not receive strong textual support at Rio+20, it is strongly supported by governments, the private sector, multilateral development banks and civil society groups. These banks pledged more than $30 billion toward the initiative's objectives, the U.S. pledged $2 billion, and several countries pledged support for domestic action.

*Lighting Africa Initiative:* A joint program of the World Bank and International Finance Corporation aimed at helping develop commercial off-grid lighting markets in sub-Saharan Africa. With the objective of providing safe, affordable and modern off-grid lighting to 2.5 million people in Africa by 2012 and to 250 million people by 2030, the program is mobilizing the private sector to build sustainable markets in Kenya, Ghana, Tanzania, Ethiopia, Senegal and Mali.

*Green Growth Action Alliance (G2A2):* A Group of Twenty (G-20) partnership initiative launched in 2012 with the goal of addressing the estimated $1 trillion annual shortfall in green infrastructure investment. The alliance calls for actions to be adopted in five target priority areas during the next three years: promote free trade in green goods and services; achieve robust carbon pricing; end inefficient subsidies and other forms of fossil fuel support; accelerate low-carbon innovation; and increase efforts to target public funding to leverage private investment.

*Sources: United Nations Foundation (2012), Lighting Africa (2012), World Economic Forum (2012).*

innovation for technological development has perhaps its greatest potential for creating an impact because it creates an environment supportive of continuous idea generation and capacity for research and development (R&D). This, in turn, creates opportunities for commercialization and financial sustainability. In contrast to many preconceptions about innovation and technology, it is important to consider all types of clean technology R&D—frontier, adaptive and absorptive—across development contexts, and by extension to consider the approaches that might accelerate each.

### TRENDS IN GREEN GROWTH INNOVATION

To date, clean technology innovation has remained concentrated in higher-income countries, though the direction of device transfer is shifting away slowly from its historic North–South directional flow. Technology innovation for the base of the pyramid (BOP) remains very low, regardless of country origin. With the exception of China, developing countries' clean technology patents have been limited to less than a dozen countries and their share of total green technology innovation is actually on the decline. However, green patent trends indicate that a new tier of developing country innovators is emerging, joining Brazil, India and China as frontier technology developers. This presents an opportunity for the international community to support the new tier of emerging economy innovators to develop frontier technologies for the BOP.

Several sectors have emerged in recent years as testing grounds for green growth innovation, with new technologies continually in development. Technology

### TABLE 1. KEY SECTORS AND TECHNOLOGIES FOR GREEN GROWTH INNOVATION

| Sector | Examples of Technologies |
|---|---|
| Electricity Access | • Smart power grids<br>• Indoor cooking stoves using renewable energy (for example, solar, wind)<br>• Off-grid technologies such as local wind turbines |
| Water Management | • Desalinization plants<br>• Wastewater treatment facilities |
| Climate Change/ Reducing Emissions | Mitigation technologies:<br>• Smart power grids<br>• Renewable energy technologies: wind, solar, geothermal, marine energy, biomass, hydro power, etc.<br>• Electric and hybrid vehicles<br>• Carbon capture and storage<br>Adaptation technologies:<br>• Higher-yield seeds (for more arid and saline soils)<br>• Drought resistant crops and cultivation practices<br>• Climate resistant infrastructure: sea walls, drainage capacity, water, forest and biodiversity management, etc. |
| Transport | • Bus rapid transit<br>• Low emission vehicles and fuels: biogas, hybrid and plug-in electric vehicles |
| Building Energy Efficiency | • Smart power grids and smart meters<br>• Thermal insulation<br>• Energy efficient lighting: energy-efficient compact fluorescent lamps, electroluminescent light sources<br>• Energy recovering stoves using thermoelectric generators |
| Agriculture | • Genetically modified crops<br>• Mechanical irrigation and farming techniques |

patenting varies by sector and scale, just as it does between country income level and region. Within the sector of climate change mitigation technologies, between 2001 and 2010 the greatest share of patents in high-income countries was issued to advanced vehicle and waste-to-energy technologies. In developing countries, it was to wind and solar, which were the third and fourth most popular issued patent categories in high-income countries. Emerging economies are also beginning to pursue patents in technology sectors in which there had been no patent activity before 2001. They are pursuing patents in sectors such as advanced vehicles, and biomass and lower-carbon cement. This hopeful trend suggests that the new tier of emerging economy innovators are not holding back from competing in sectors in which they have no historical precedent as producers. However, the pace of green growth innovation in least developed countries (LDCs) remains very slow.

### EXAMPLE: INVESTMENT AND R&D IN THE GLOBAL RENEWABLE ENERGY SECTOR

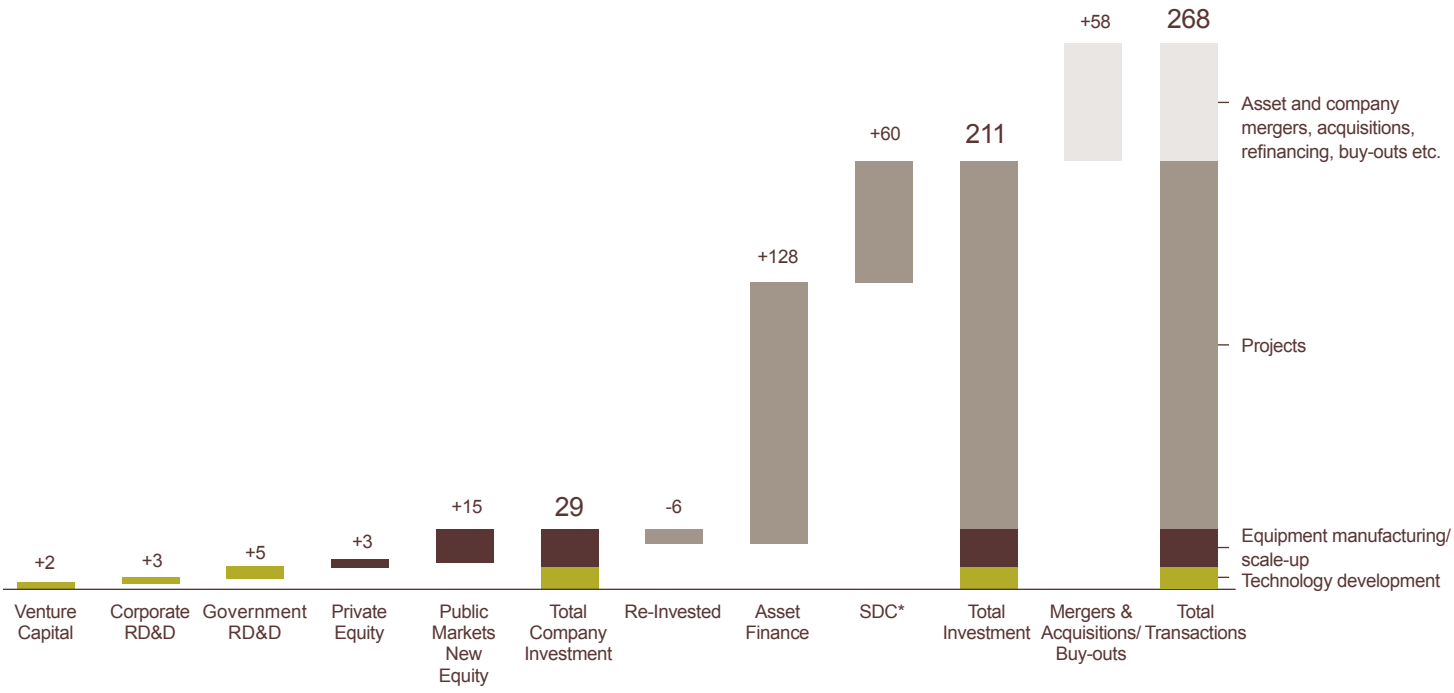
In terms of the scale of technologies, one can look to renewable energy financing data for some illustrative examples. The United Nations Environment Program and Bloomberg New Energy Finance estimate that about $268 billion was transacted in the renewable energy sector in 2010, of which $211 billion was new investment (see figure 2). This number is estimated to have reached $263 billion in 2011,[2] a roughly 25 percent increase over the 2010 global figure. Distributed energy technologies have garnered an increasing share of global renewable energy investment dollars during the past several years. In 2010, only slightly more than one-quarter of total renewable energy investment went to distributed technologies. The vast majority went to developed countries. This is largely due to domestic policy incentives for solar photovoltaics in Europe. In fact, 57 percent of distributed energy investments in 2010 were spent in Germany alone. The amount of investment in utility-scale energy companies and projects was roughly equal between developed and developing countries in 2010.[3]

Notably, in 2010 the investment in renewable energy in developing countries for the first time exceeded that of developed countries ($72 billion versus $70 billion; see figure 3). Development bank finance contributed at least $13 billion in project finance, mostly in the form of concessional loans. That year, investment in Africa rose fivefold, in Latin America it rose nearly threefold, and in Asia it rose 31 percent. However, 83 percent of developing country renewable energy investment that year went to the three largest emerging economies—China, India and Brazil—and the vast majority was spent on asset finance, not R&D. Furthermore, despite the tremendous increase in investment in Africa, total new financial investment in renewable energy remains very low ($3.6 billion in 2010) on the continent.[4]

R&D investment across all sectors of the economy, green growth and otherwise, reached $1.3 trillion in 2011. This is a 17 percent increase since 2008. Investments were led by the United States (34 percent), China (13 percent) and Japan (12 percent).[5] All other countries outside these three, the European Union and India accounted for only 3 percent of general R&D spending in 2011. However, U.S. dominance of R&D investment spending is shifting toward the major Asian economies and Brazil. Economic and technological capacity growth in the largest emerging economies, particularly India and China, have also created a trend of reverse flow of R&D investment from emerging to developed nations. Still, R&D spending as a percentage of gross domestic product remains in the low single digits across all countries—an average of 1.9 percent in 2011.

However, renewable energy R&D investments have not been keeping pace. In 2011, only 4 percent, or $9 billion,

**FIGURE 2. UNEP/BNEF ESTIMATES FOR 2010 GLOBAL RENEWABLE ENERGY TRANSACTIONS (BILLIONS OF DOLLARS)**



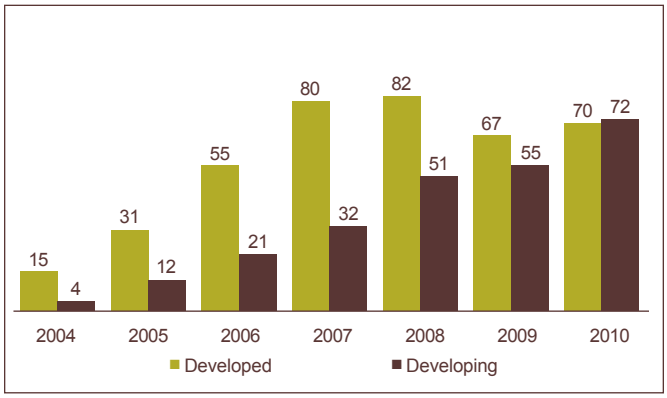

SDC = small distributed capacity. Total values include estimates for undisclosed deals. * data based on estimates from various industry sources

*Source: Bloomberg New Energy Finance, UNEP*

*Note: Figure 2 shows in detail how the $268 billion in total global renewable energy transactions for 2010 is reached. The segmented bar furthest to the right on the chart shows the four following categories of transactions: 1) Asset and company mergers, acquisitions, refinancing, buy-outs etc; 2) Projects; 3) Equipment manufacturing/scale-up; and 4) Technology development. The other bars to its left break down the four categories into various color-coordinating subcategories.*

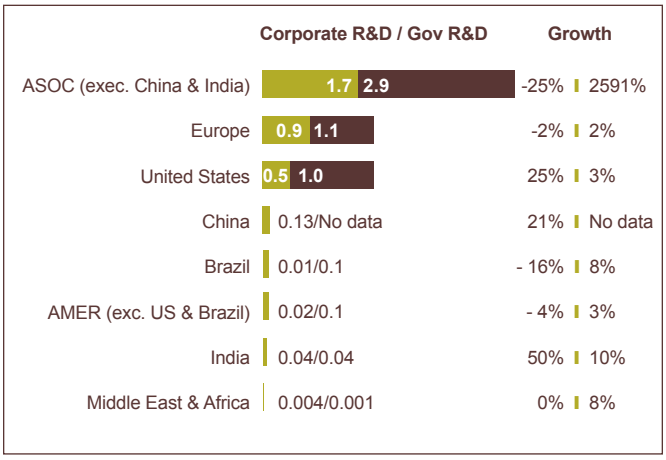
## FIGURE 3. UNEP/BNEF ESTIMATES FOR TRENDS IN RENEWABLE ENERGY SUPPORT

### (A) Financing New Investment in Renewable Energy (Billions of Dollars), Developed vs. Developing Countries




New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals

### (B) Corporate and Government R&D for Renewable Energy by Region (Billions of Dollars), 2010, and Growth on 2009




*Sources: (a) United Nations Environment Program and Bloomberg New Energy Finance (2011); (b) Bloomberg, Bloomberg New Energy Finance, International Energy Agency, International Monetary Fund, and various government agencies.*

was spent on R&D, despite the fact that alternative energy R&D investments more than doubling between 2004 and 2010.[6] Furthermore, excluding the stimulus boosts, global investment in energy research, development, demonstration and development (RDD&D) in developed countries has actually only marginally increased in real terms since 1974.[7] Additionally, global renewable energy investment in the first quarter of 2012 was at its lowest level since the height of the recession in early 2009, signaling a global decline in public financing of alternative energy with the expiration of stimulus programs.[8]

With regard to renewable energy R&D investment, in 2010, the largest regional investors were Asia and Oceania, which accounted for slightly more than half of global R&D investment in renewable energy that year (see figure 3). Most R&D financing came from the public sector, as corporate R&D budgets shrank in the wake of the global financial crisis. Early stage venture capital financing rose 41 percent to $930 million in 2010. Solar received the largest share of any technology type.[9] Biofuels received the next largest share, followed by wind. Though it continues to receive a tiny share of global R&D investment, marine energy saw the greatest investment growth of any clean energy technology type in 2010.

## CATALYZING NEW APPROACHES

As companies increasingly incorporate social equity into their sustainability agendas, and as growth opportunities in emerging markets continue to outperform those in developed countries, corporate interest in innovation for emerging economies can be expected to increase. Yet investment in innovation for the BOP remains largely nonexistent. Therefore, a major question for the sustainable development agenda is how to incentivize green BOP innovation from the private sector. Many policy and IP tools exist to promote behavioral change and spur technological innovation, though they vary widely across countries. In addition, dozens of financial products have also been created to diffuse and reduce risk in technology investment. Hundreds of initiatives exist to promote natural resource sustainability and poverty alleviation in developing countries. However, major gaps remain in international collaboration for poverty alleviation.

New green innovation initiatives or partnerships might hasten the pace and scale of innovation, stimulate international venture capital markets, and broaden international cooperation across public and private partnerships for RDD&D. The gaps in green growth

innovation where private sector investment could have a substantial impact include:

- Facilitating South–South collaboration.
- Enhancing greater North–South collaboration.
- Encouraging greater frontier innovation in the new tier of emerging economy innovators.
- Supporting adaptive innovation for the BOP from all countries.
- Investing in support for absorptive innovation in all countries.
- Providing business advisory support to developing countries.
- Increasing financing for IP sharing and financial products to lessen the risk of entrepreneurial investments.

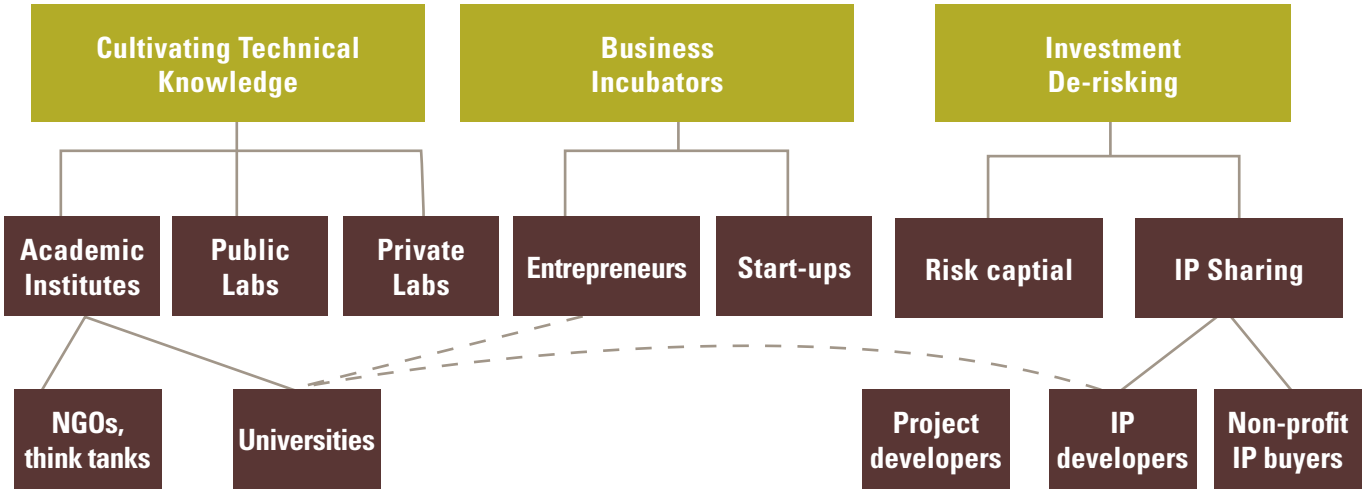
Of these, the least commonly supported areas include long-term finance, business acceleration, frontier and adaptive BOP innovations, and South–South collaboration.

New approaches to green growth innovation would both build capacity for technology development and adoption, and encourage private sector engagement in developing country research and innovation for green growth. The most effective approaches should reflect all the following factors:

- *Relevance to the challenges of green growth.* The ideal international architecture will be able to support breakthrough technology development at small, medium and large scales.
- *Capability of stimulating frontier, adaptive and absorptive innovation*. Adaptive innovation could be the key to meeting many LDCs' clean development needs, and absorptive innovation programs could be encouraged throughout the developing world. Policies to stimulate absorptive capacity must increase the quality of higher education, retain in-country talent, stimulate technology "discovery" at all levels of innovation (from household through the research laboratories) and promote economy-wide openness to new technologies.
- *Support for innovation across the technology value chain.* Technology deployment can be encouraged via financial support, logistical support for supply chain development and security, and consumer marketing to improve market penetration. This includes substantial investment in business advisory services to attract international venture capital and to take successful start-ups to full commercial scale.
- *Financial innovation to lessen the risk of private investment.* Innovative financial products can leverage public investments by lessening the risk for private capital. Examples include first loss funds, sovereign risk insurance and collateralized loans with flexible interest rates dependent on project outcomes. There are many funds that support this objective—such as the Clean Technology Fund of the Climate Investment Funds, which provides project support—as well as recent initiatives that are looking to scale this up by tapping into private capital. To date, most of the funding has gone to support the deployment of proven technologies in developing countries. Little focus has been on providing support for lessening the risk at earlier stages of the RDD&D continuum.
- *Value addition to existing institutions.* Any new approaches should be complementary to existing international initiatives that aim to stimulate clean technology RDD&D, such as the UNFCCC Technology Mechanism, the Consultative Group on International Agricultural Research, the Clean Energy Ministerial, the Green Climate Fund and Infodev Climate Innovation Centers. It will be important to understand not only the gaps in services provided by these organizations but also the programs that have been most successful so they can be replicated in other countries and sectors.
- *Attractiveness to investors, policymakers and developing countries.* In this era of fiscal austerity, it is essential to create an infrastructure with sufficient incentives to leverage public financing from developed countries and offer real rewards to the private investors.

Although there are many concrete possibilities, jump-starting the green innovation ecosystem in any given country's context will require an approach across all aspects of the innovation spectrum. This implies a need to cultivate technical knowledge, to encourage and foster the existing entrepreneurial culture and to connect entrepreneurs to financing. Figure 4 presents this three-

**FIGURE 4. A THREE PART CHALLENGE FOR JUMP-STARTING GREEN INNOVATION**




*Source: Brookings.*

part challenge for jump-starting the green innovation system. A system to address these three issues could work through universities, research organizations (both for-profit and nonprofit), academic institutions and start-ups to reach individual researchers, financiers and budding entrepreneurs. This network would be complemented by a set of funds to deploy risk capital for the diffusion of technologies that have been proven at the demonstration stage.

## CONCLUSION

Green growth provides a route for realizing economic, environmental and development goals. It offers an opportunity to make existing heavy industries more sustainable while simultaneously encouraging new industries and economic diversification. Central to the green growth strategy is technological innovation and the establishment of creative, integrated, private and public sector approaches to support innovation in developing countries. It is therefore necessary to:

1. Expand the scope of innovation support to BOP and low-margin innovations.
2. Work creatively to better understand and address the challenges of IP sharing.
3. Pioneer new business models and financing structures.
4. Cultivate a broad-based technical knowledge in both emerging economies and the LDCs.

## APPENDIX: DEVELOPING COUNTRY GREEN GROWTH GAPS AND OPTIONS TO ALLEVIATE THEM

| Gap | Geography | Options |
|---|---|---|
| North–South collaboration | All countries | • Stronger IP regimes to support strategic research partnerships, joint ventures and cross-border enterprise development<br>• Dedicated funds and challenge programs requiring North–South collaboration<br>• Opportunities for international study—grants, scholarships, etc<br>• Financial instruments to lessen risk and thus encourage foreign investment |
| South–South collaboration | Developing, emerging countries | • Regional science foundations to identify common needs, pool funding and avoid research overlaps<br>• Strengthen top-performing university networks<br>• Scientific and entrepreneur study abroad programs with dedicated official development assistance grants |
| Frontier innovation for the BOP | New tier of emerging economy innovators | • Dedicated international venture capital funding and risk capital for developing country start-ups, through challenge/prize programs<br>• Training for developed country firms in understanding BOP needs, conducting demonstration tests, and developing supply chains<br>• Formal extension/ cooperative/ internship programs for university students |
| Adaptive innovation for the BOP | All countries | • BOP innovation from developed countries, through government-funded R&D, subsidies, advanced market commitments, compulsory licensing, open source innovation, patent pools bilateral and multilateral market access agreements, and applied research networks<br>• BOP innovation in developing countries, through dedicated official development assistance funding to LDCs, national and community-level technology “discovery” programs, higher education networks, strengthened Intellectual Property rights, challenge programs, advanced market commitments, and applied research networks |
| Absorptive innovation | All countries | • Financial support for early adopters and enterprise training programs<br>• Adoption incentives through subsidies, tax credits, feed-in tariffs |
| Business advisory support | Developing, emerging countries | • Business services such as incubation centers, business education at technical universities, business plan competitions, deployment-focused “study abroad” programs for professors and university students, community demonstration competitions, networking events and online collaboration tools |
| IP sharing and implementation assistance | Developing countries | • Financial incentives to encourage sharing of patent information and provision of implementation assistance<br>• Nonfinancial incentives to do the same (patent commons, patent pools, professional “exchange” programs for implementation advisory) |
| Long-term financial support | Developing countries | • Financial products to lessen the risk of investments in technology development in developing countries (for example, first loss fund, sovereign risk insurance, concessional loans) |

5. Create a support structure to enable entrepreneurs to expand their own expertise and access to networks.

Indeed, without these creative approaches and the new technologies and market transformations they engender, we almost certainly will not be able to realize the goals of universal access to clean energy, water and sanitation, or the broader environmental goals of climate stabilization and biodiversity protection, while encouraging economic growth and vitality across the spectrum of development contexts. The appendix provides further details on gaps to delivering green growth in developing countries and the options to address these gaps.

## ENDNOTES

[1] International Energy Agency (2010).

[2] Morales (2012).

[3] United Nations Environment Program and Bloomberg New Energy Finance (2011, 44).

[4] Ibid., 14.

[5] Batelle (2010, 3).

[6] United Nations Environment Program and Bloomberg New Energy Finance (2011, 13).

[7] Kerr (2010, 8).

[8] Morales (2012).

[9] United Nations Environment Program and Bloomberg New Energy Finance (2011, 33).

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