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Building Competitive Green Industries:

The Climate and Clean Technology Opportunity for Developing Countries

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Growing Innovation

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The report "Building Competitive Green Industries: The Climate and Clean Technology Opportunity for Developing Countries" is available at www.infodev.org

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*info*Dev, a global trust fund program in the World Bank Group, supports growth-oriented entrepreneurs through creative and path-breaking venture enablers. It assists entrepreneurs to secure appropriate early-stage financing; convening entrepreneurs, investors, policy makers, mentors and other stakeholders for dialogue and action. We also produce cutting-edge knowledge products, closely linked to our work on the ground.

About *info*Dev's Climate Technology Program

The Climate Technology Program (CTP), housed at *info*Dev, empowers developing countries to proactively and profitably adapt, develop, and deploy climate-smart technologies and business models. The CTP is creating a global network of Climate Innovation Centers (CICs) that provide a country-driven approach to addressing climate change and fostering green growth. The CICs are designed as locally owned and run institutions that provide a suite of services and venture financing that address the specific needs of local climate technology SMEs and entrepreneurs. At the global level, the CTP is providing linkages between CICs by facilitating market entry, access to information, and financing for the private sector, while also offering important tools for policy makers to measure and improve domestic climate innovation activities. Currently, the program is establishing CICs in eight countries: Kenya, the Caribbean, Ethiopia, Ghana, India, Morocco, South Africa and Vietnam.

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Foreword

Building Competitive Green Industries: The Climate and Clean Technology Opportunity for Developing Countries

By Anabel Gonzalez
Senior Director, Global Practice on Trade and Competitiveness

As we confront the challenge of climate change – a potentially lethal threat to our planet – it is vital that policymakers in every country resolve to take effective action to limit greenhouse-gas emissions. The technical challenge may seem daunting, yet taking far-sighted action to restrain climate-damaging emissions can have a net positive effect on the economy. As shown by a major 2014 World Bank Group report – "Climate-Smart Development: Adding Up the Benefits of Actions that Help Build Prosperity, End Poverty and Combat Climate Change" – making climate-smart investments can have, overall, a positive economic impact, particularly among the largest greenhouse-gas-emitting economies in the developed world.

Reinforcing that analysis' hopeful message, this new report shows that developing countries – like the world's industrialized economies – can reap significant positive benefits by investing in technologies to restrain emissions and by developing new clean technology industries that can build resilience and limit further climate damage.

This report analyzes the economic opportunity that developing and emerging countries can now seize, if they adopt policies to fight climate change and invest in low-carbon growth. This report, for the first time, quantifies the size of expected investment in clean technologies in the developing world over the next decade – and it finds that the opportunity is vast: the expected investment across a wide range of clean technology sectors, just in the world's developing and emerging economies, will exceed $6.4 trillion over the next decade. Better still, about $1.6 trillion of that total offers an opening for small and medium-sized enterprises (SMEs) –key drivers of future job creation. SMEs also serve the local, rural and "base of the pyramid" markets that are often underserved by larger firms. Moreover, developing economies are already on the right track, with US$112 billion in clean-tech investments in 2012 – a 19 percent year-over-year increase.

Doing the right thing for the environment could unlock a significant potential for a pathway towards a sustainable green economy. Creating competitive economic sectors is critical to stimulating the job growth that is indispensable to achieving the World Bank Group's twin goals: eliminating extreme poverty and fostering shared prosperity. Fostering home-grown climate and clean technology industries in developing countries can create a sustainable and wealth-producing sector of the economy, while simultaneously addressing such urgent development priorities as access to clean and affordable energy, clean water and climate-resilient agriculture.

In welcoming this hopeful analysis, policymakers worldwide can benefit from its clear-sighted calculation that the clean technology transition can deliver strong new economic benefits even as it protects the long-term well-being of our fragile environment.

Acknowledgments

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The study design benefited from discussions with and guidance from numerous World Bank colleagues, in particular Valerie D'Costa, Jonathan Coony, Esperanza Lasagabaster and Paulo Correa. The team gratefully acknowledges the comments and advice provided by reviewers Mark Dutz, Parth Tewari, Oliver Knight and Pablo Benitez.

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Abbreviations

ABPP	Africa Biogas Partnership Program
BoS	Balance of systems
BRT	Bus rapid transit
CAPEX	Capital expenditure
CDM	Clean development mechanism
CER	Certified emission reduction
CERT	Central Electricity Regulatory Commission
CGIAR	Consultative Group on International Agricultural Research
CHP	Combined heat and power
CIC	Climate Innovation Center
COMESA	Common Market for Eastern and Southern Africa
CSA	Climate-smart agriculture
CSP	Concentrated solar power
CWC	Central Warehousing Corporation
DCR	Domestic content requirement
EAC	East African Community
E-bike	Electric bike
EIA	U.S. Energy Information Administration
EPC	Engineering, procurement, and construction
EWEA	European Wind Energy Association
ETS	Emissions Trading Scheme
EV	Electric vehicle
FAO	Food and Agricultural Organization of the United Nations
FCI	Food Corporation of India
FIT	Feed-in tariff
GDC	Geothermal Development Company
GDP	Gross domestic product
GHG	Greenhouse gas
ICT	Information and communication technologies
IDB	Inter-American Development Bank

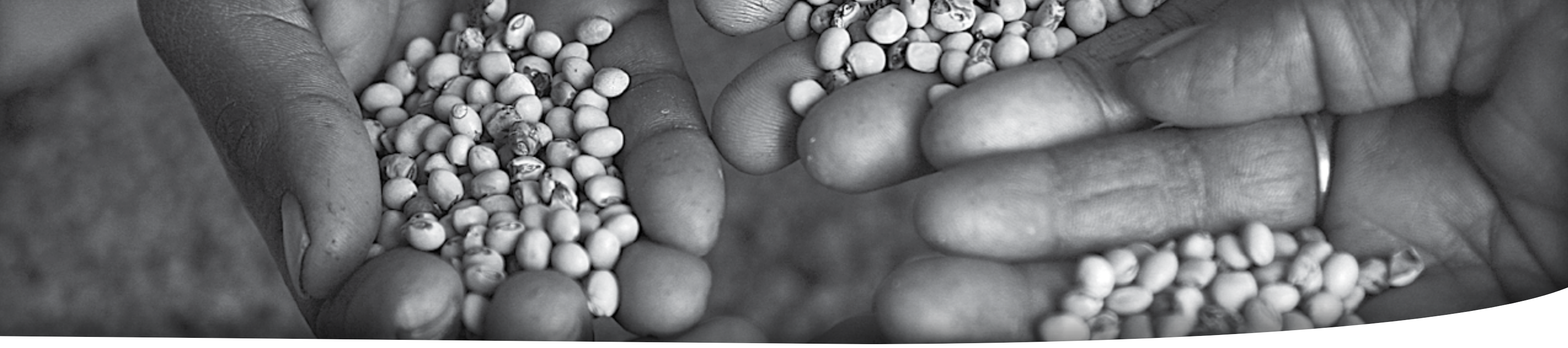


Photo: Simone D. McCourtie / World Bank.

IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IPR	Intellectual property rights
IREDA	Indian Renewable Energy Development Agency
KCJ	Kenya Clean Jiko
KENDBIP	Kenya National Domestic Biogas Program
KJEL	Kenya Jatropha Energy Limited
KWH	Kilowatt hour
MDG	Millennium development goal
MMSME	Indian Ministry of Micro, Small and Medium Enterprises
$MMTCO^2E$	Million metric tons of carbon dioxide equivalent
MW	Megawatt
NAPCC	National Action Plan on Climate Change
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NEMA	Kenya's National Environment Management Authority
O&M	Operations and maintenance
PAC2	Brazil's National Growth Acceleration Program
PCT	Patent Cooperation Treaty
PV	Photovoltaics
R&D	Research and development
RD&D	Research, development and demonstration
RET	Renewable energy technology
SHP	Small hydro power
SME	Small and medium enterprise
SWC	State warehousing corporations
SWH	Solar water heaters
TCO_2e	Tons of carbon dioxide equivalent
UNEP	United Nations Environment Programme
WRI	World Resources Institute

All dollar amounts are U.S. dollars unless otherwise indicated.

Executive Summary

Climate Change Provides Developing Countries with an Opportunity to Build Local Green Industries

Climate change will have its largest impacts on developing countries, with poor populations particularly hard hit and unable to adequately adapt (World Bank, 2013a). There are ongoing efforts to assist developing countries with efforts to mitigate and adapt to climate change through the deployment of appropriate climate and clean technologies. However, the main thrust of many of these efforts is to transfer technology from the developed world without regard to local industry involvement. There is an opportunity for developing countries to pursue a complementary approach, emphasizing building up the capabilities of local firms to participate in the business opportunities surrounding climate change. Climate change therefore represents an opportunity for developing countries to build local green industries that can drive sustainable economic growth and provide environmental benefits.

This report offers insight to policy makers and other stakeholders seeking to develop competitive green industries[1] in developing countries. It provides an overview and estimate of the market opportunity for climate and clean technology business in developing countries over the coming decade. It identifies which aspects of these markets are most accessible to local firms and to small and medium enterprises (SMEs) in particular. Using a newly gathered set of firm data, it identifies which parts of the value chain are already being targeted by local industry. Finally, it provides a set of actions that can be considered for countries that intend to build up local green industries.

Developing Countries Are Increasingly Driving Growth and Innovation in the Global Climate and Clean Technology Market

Until recently, businesses and governments in the developed world have been driving growth and innovation in clean technology markets, but emerging economies and developing world markets are increasingly powering the sector as shown in Figure E1.[2] In 2012, clean technology investment rose by 19 percent in developing countries (to $112 billion per year) compared with an overall decline of 12 percent globally (to $244 billion per year), suggesting that clean technology investment is shifting towards developing economies in the near term.

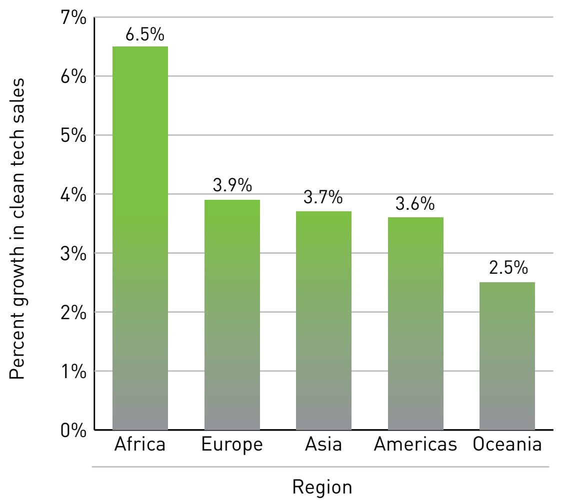
This accelerating shift from the developed to the developing world is driving innovation as technologies, processes, and financing

1 In this report, the term "green industry" refers to services and technologies aimed at contributing to reducing negative environmental impacts or addressing the consequences of various forms of pollution. This is not to be confused with the term "greening of industries," an effort under which traditional industries improve their resource productivity and environmental performance (UNIDO, 2011).

2 This report uses the term "clean technology" to cover the range of technologies that provide climate mitigation or adaptation benefits or positive environmental benefits. A typology of these technologies and related industries is included in Chapter 2.

Photo: World Bank.

FIGURE E1. Growth in clean technology sales, by region (2012)



Source: U.K. Department for Business, Innovation and Skills (BIS).

mechanisms are adapted to suit local conditions and new innovations are emerging to address local customer needs. It is also opening up opportunities for ambitious entrepreneurs who are well positioned to capitalize on the sector's growth.

Furthermore, with this accelerating shift, the ability of clean technology to foster job growth and stimulate innovation makes it particularly relevant to developing countries. Clean technology is a growing employment sector globally and green jobs compare favorably to jobs in other sectors: they tend to be more skilled, safer, and better paid. Innovation is central to the development of clean technology products and environmental technologies account for a significant proportion of global patent applications.

However, the unique character of clean technology — such as high upfront capital requirements and longer payback periods for investors — means it has greater difficulty attracting venture capital and requires more public investment than traditional sectors. This investment obstacle is even more pronounced in developing countries where payback scenarios are more uncertain and SMEs and new ventures are riskier.

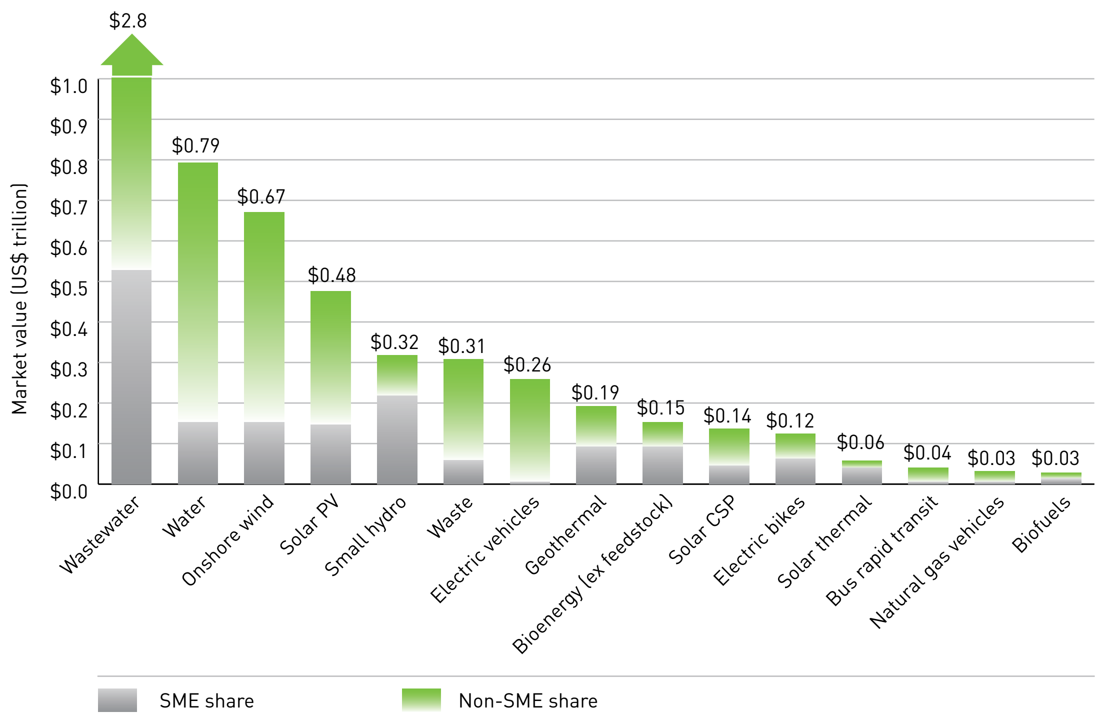
A $1.6 Trillion Market Is Accessible to SMEs in Developing Countries Over the Next Decade

This report illustrates the nature and likely size of the clean technology opportunity for SMEs in 145 developing countries over the next decade.[3] In that time, expected investment across 15 clean technology sectors in these developing countries will top $6.4 trillion overall. Of that total market, roughly $1.6 trillion will be accessible to SMEs, as shown in Figure E2. Even when excluding China, India, Russia and Middle Income Europe, these

Photo: World Bank.

3 In this report, an SME is defined as an institution with a maximum of 300 employees, maximum revenues/turnover of $15 million, and maximum assets of $15 million.

FIGURE E2. Market size through 2023 for 15 clean technologies in developing countries ($ trillion)



Source: Authors' analysis.

Photo: Danilo Pinzon / World Bank.

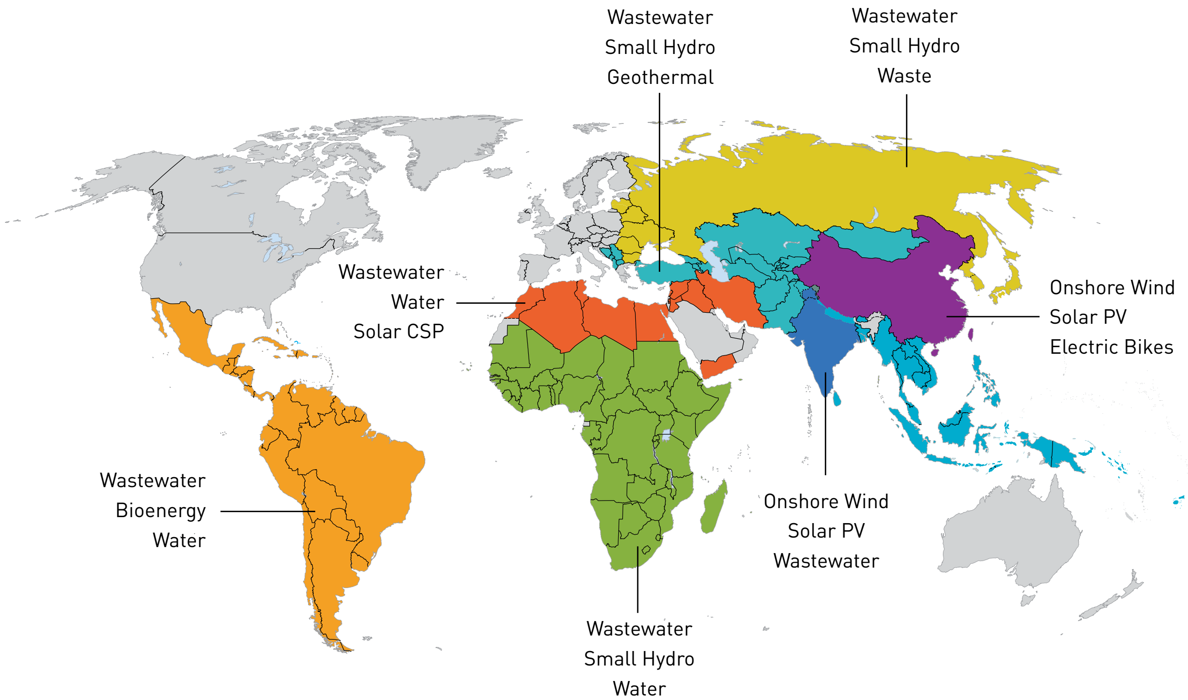
opportunities are still significant: $4.1 trillion overall, of which $1.0 trillion is accessible to SMEs (see Chapter 2 for more detail).

The SME opportunity is largest in the wastewater treatment sector, which makes up about one-third of the total, with small hydro, water treatment, onshore wind power, solar PV, geothermal and bioenergy the next largest SME opportunities.

A number of the renewable and nonrenewable technologies are expected to present significant opportunities for SMEs as well and they are each discussed in turn with the top three opportunities for each region highlighted in Figure E3. While energy efficiency is not covered specifically, both the abatement potential and SME opportunity are large.

Opportunities are available for SMEs across the entire clean technology value chain, but are particularly prevalent in minor equipment manufacture, installation, civil works, retailing, and operations and maintenance (O&M) activities. Knowledge of local markets, the need for specialization, and lower financial and technical barriers to entry make these activities especially

FIGURE E3. Top three regional opportunities for SMEs



Source: Authors' analysis.

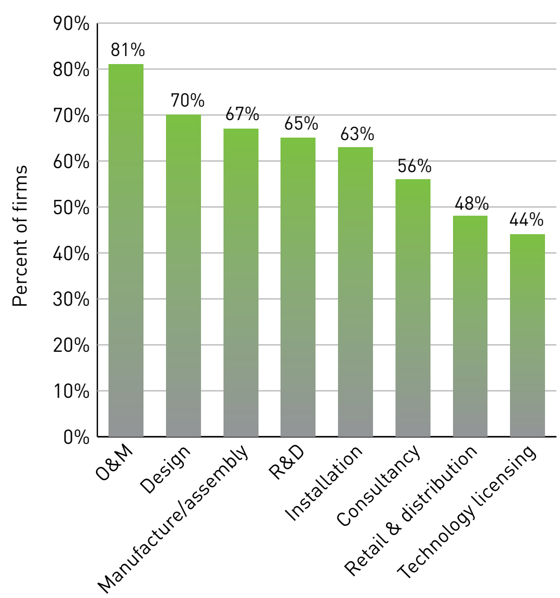
accessible to SMEs. While some opportunities exist in major equipment manufacturing, SMEs tend to face barriers such as high startup capital costs and the need for highly technical expertise and equipment.

SMEs Are Already Operating and Innovating Across Clean Technology Value Chains

The report examines three technology areas across India and Kenya. The focus is on solar technology in India and bioenergy in Kenya, while climate smart agriculture is explored across both countries.

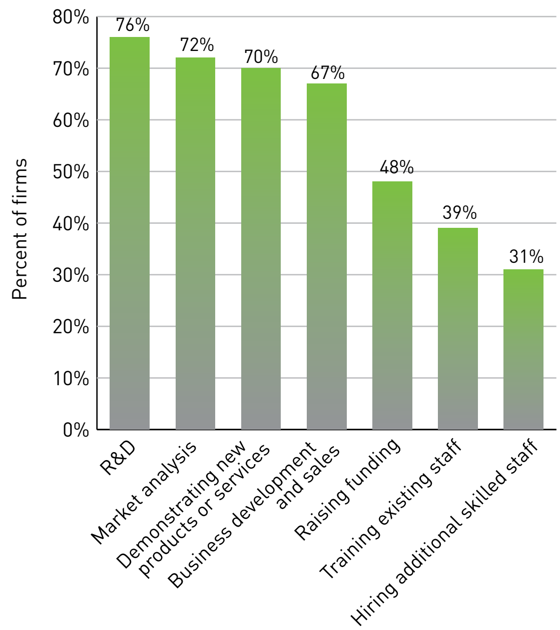
These case studies reveal that clean technology SMEs are already working in the value chain segments with the most opportunities for SMEs. Most firms in India said they worked in several different parts of the value chain, as shown in Figure E4, with over 70 percent of firms saying they worked in design and/or operations and maintenance, and over 60 percent saying they

FIGURE E4. Value chain activities in which Indian clean technology firms are involved



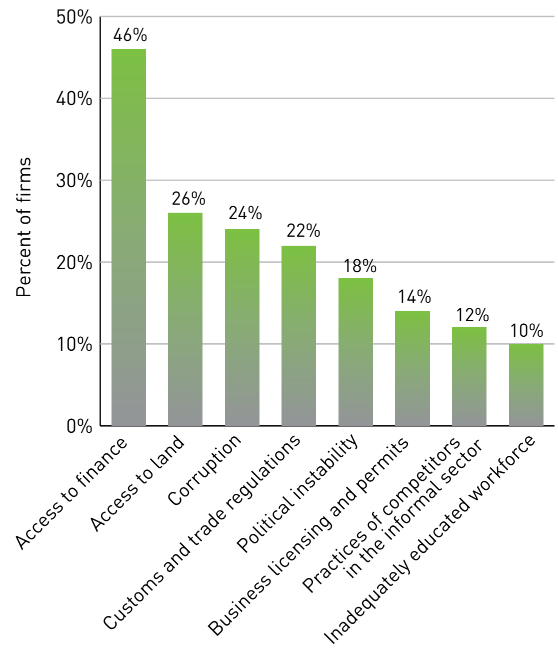
Source: Survey of clean technology firms in India undertaken in July and August 2013.

FIGURE E5. Innovation activities undertaken by clean technology SMEs in Kenya



Source: Survey of clean technology firms in Kenya undertaken in July and August 2013.

FIGURE E6. Most common barriers cited by clean technology SMEs in India



Source: Survey of clean technology firms in India undertaken in July and August 2013.

worked in one or more of installation, manufacture, and assembly, and/or R&D.

The potential for local innovation is demonstrated by the clean technology SMEs interviewed for this report. Innovation in Kenyan SMEs is undertaken through a breadth of activities as shown in Figure E5, including research and development (R&D), business development, new products and services, and innovative financing options.

Removing Barriers for Clean Technology SMEs Could Promote Faster Growth of Local Green Industries

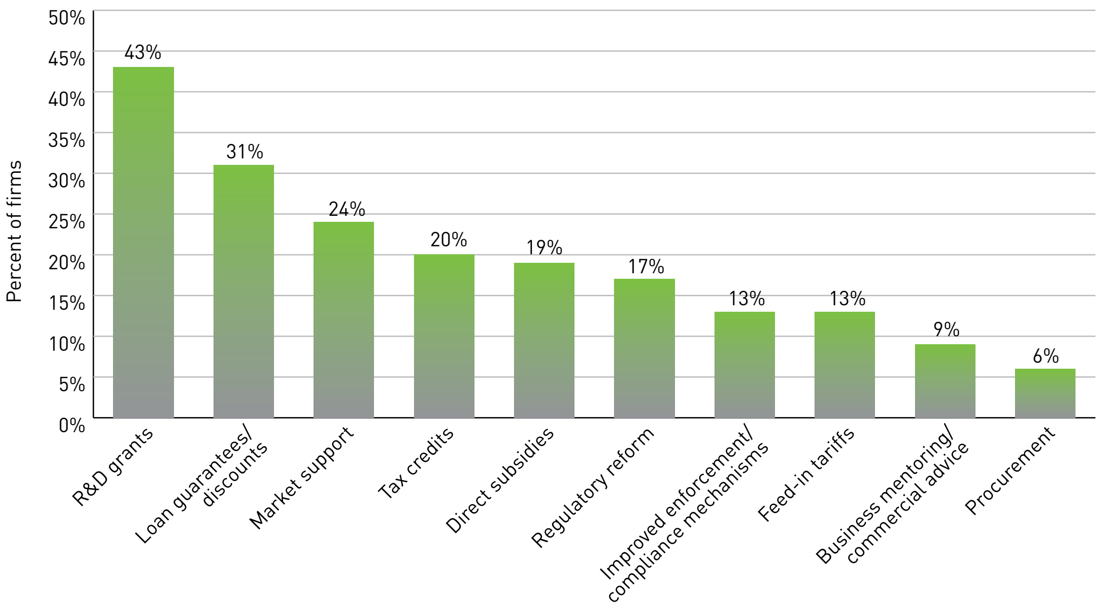
Accessing these clean technology opportunities comes with a number of challenges for SMEs. Clean technology SMEs find it difficult to access the capital needed to grow and expand, with almost half of Indian SMEs (see Figure E6) and two-thirds of Kenyan SMEs surveyed for this report rating access to finance as a major constraint. It is also a risk to rely on government policy to sustain markets, as is the case for most renewables, major water and waste public works projects, and new clean transport options. The required technical capacity can also be a challenge, especially in developing countries where highly skilled workforces are still nascent.

Nevertheless, the SMEs surveyed were optimistic about the future prospects of their own businesses and of the clean technology market more generally. They tended to have a strong history of growth, with 90 percent of firms experiencing revenue growth even through the global economic downturn. Most firms are planning to hire additional staff. About 90 percent of surveyed firms are fairly or very confident in the business environment for clean technology.

To make the most of this opportunity that clean technology provides, SMEs would benefit from a supportive and reliable policy and regulatory environment that favors more resource efficient technologies and processes. Targeted business support can also help SMEs in this space thrive, in such ways as indicated in Figure E7.

With a $1.6 trillion clean technology opportunity available to developing world SMEs over the next decade, policy makers have a chance to stimulate local innovation and capture economic value by

FIGURE E7. Areas for government support identified by clean technology SMEs in Kenya



Source: Survey of clean technology firms in Kenya undertaken in July and August 2013.

supporting the dynamism of their clean technology SMEs.

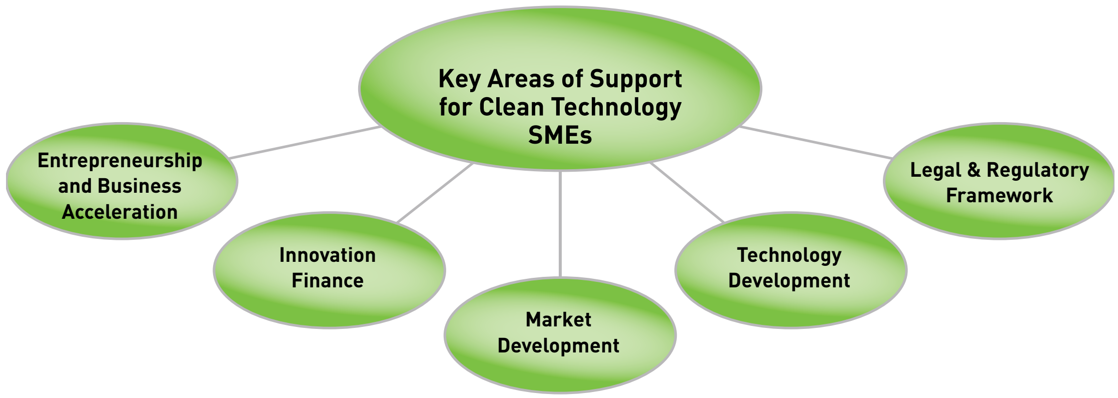
Actions to Support Clean Technology SMEs

This report describes the importance of SMEs to the growth of competitive clean technology industries. It also illustrates that opportunities exist for developing country SMEs across clean technology industries and value chains. However, the growth of these firms is also dependent on consistent support to overcome the challenges characteristic of clean technology firms, including higher upfront capital requirements, longer payback periods for investors and a heavier reliance on government policy than other technology sectors.

Five areas of action should be considered by governments, development agencies and other public and private actors to support clean technology SMEs in developing countries. These areas, illustrated in Figure E8, are: entrepreneurship and business acceleration, innovation finance, market development, technology development and the legal and regulatory framework.

Photo: *info*Dev.

FIGURE E8. Key areas of support for clean technology SMEs



Policy makers and other stakeholders can draw upon a broad tool-box of instruments in each of these five areas, listed in Appendix C and discussed in Chapter 7.

- **Entrepreneurship and business acceleration:** There is a range of programs for businesses, as well as international collaborations and networks, which countries and businesses can draw upon to help strengthen SME entrepreneurship and business acceleration in clean technology sectors. Here, countries can pursue programs offering direct technical assistance and the linking of foreign investors with local clean technology SMEs for technology development and/or production capacities. More hands-on and in-country business incubation is also expanding, such as *info*Dev's Climate Innovation Centers.
- **Innovation finance:** There are various instruments available to support early stage financing and risk capital for clean technology SMEs, to complement traditional financing sources. These include providing soft loans and loan guarantees and stimulating seed and venture capital investment. On the demand side, there is a significant opportunity to establish technology-specific consumer credit facilities, which have proven particularly useful for technologies that require higher up-front investments such as renewable energy systems.
- **Market development:** A range of instruments aim to increase demand for the products and services of local SMEs, and facilitate the overall growth of the clean technology market. For renewable energy these include portfolio standards, renewable energy certificates and feed-in tariffs. Clean technology markets can also receive a rapid boost through strict sustainable procurement policies, manufacturer standards, product labeling and product testing and certification, as well as indirect and/or "soft" interventions such as education, campaigns and performance rankings.
- **Technology development:** Instruments designed to stimulate technology development include R&D tax credits, research grants, publicly funded competitive research collaborations, competitions, public investment in R&D, public or private agreements on technology cooperation, demonstration projects and applied research networks.
- **Legal and regulatory framework:** The overall enabling framework for clean technology SMEs can be strengthened by implementing a number of legal and regulatory policies, including sector-specific tax incentives, cap-and-trade emission schemes, emission reduction credits, taxation on pollution or natural resource use, import tax reductions or waivers and incentives to attract skilled labor. These can be designed to create business incentives and/or obligations that address both the supply and demand side of clean technology markets.

Policy makers, in particular, must adopt and adapt these instruments to fit their country's circumstances. They should also seek to mitigate key risks, including failures to coordinate policy design and implementation, market distortions, and the effects of policy discontinuity.

It is also important to design and implement these instruments in parallel, as part of a broader, national strategy to support clean technology SMEs. Policy makers are advised to take into account their national circumstances and focus attention on developing policy interventions on "fertile ground," as opposed to supporting technologies and sectors that do not have the support of already existing human and natural resource capacities.

In order to achieve complementarities and policy coherence, policy makers are also advised to survey the portfolio of existing policies and conduct a harmonization analysis, that is, to understand if and how other policies and national economic circumstances stand to conflict with, or undermine, planned interventions to support clean technology SMEs.

To illustrate policy considerations within specific national contexts, the report offers case studies of national programs targeting SMEs within green industry. These include South Korea's Green Growth Strategy, India's National Solar Mission, Thailand's Energy Conservation Program, and Ethiopia's Climate Resilient Green Economy Strategy.

Photo: Graham Crouch / World Bank.

Chapter 1

The Climate and Clean Technology Opportunity for Developing Countries

Main Points

- Climate change represents an opportunity for developing countries to build local green industries that can drive sustainable economic growth as well as environmental benefits.
- Climate and clean technology sectors are intrinsically innovative and compare favorably to other sectors in terms of innovation output, job creation and job quality.
- This report provides an overview and estimate of the market opportunity for climate and clean technology business in developing countries over the coming decade, with particular attention to opportunities and barriers for SMEs. Using the results of a new survey of clean technology firms in India and Kenya, the report identifies key barriers for these firms and which parts of the value chain are already being targeted by local SMEs.
- Finally, the report provides a set of actions that can be considered for countries that wish to support innovative SMEs within local green industries.

The Clean Technology Opportunity

Climate change will have its largest impacts on developing countries, with poor populations particularly hard hit and unable to adequately adapt (World Bank, 2013a). There are ongoing efforts to assist developing countries with efforts to mitigate and adapt to climate change through deployment of appropriate climate and clean technologies. However, the main thrust of many of these efforts is to transfer technology from the developed world, with little emphasis on building up the capabilities of local industries to participate in the business opportunities surrounding climate change. There is an opportunity for developing countries to take a complementary approach. Climate change represents an opportunity for developing countries to build local green industries that can drive sustainable economic growth as well as environmental benefits.

This report offers insight to policy makers and other developing country stakeholders seeking to develop competitive green industries. It provides an overview and estimate of the market opportunity for climate and clean technology business in developing countries over the coming decade.[4] It identifies which aspects of these markets are most accessible to local firms and SMEs in particular. Using a new set of firm data, it identifies which parts of the value chain are already being targeted by local companies. Finally, it provides a set of policy options and guidance that can be considered for countries that intend to build up local green industries.

4 Market projections in this report cover the ten-year period 2014-2023.

Photo: © Arne Hoel / World Bank.

The report is organized as follows. Chapter 1 defines clean technology[5] and describes which sectors are covered in the report and why. It then compares clean technology to other technology sectors in terms of investment, innovation and jobs.

Chapter 2 examines the projected size of clean technology investment globally and then delves deeper into the opportunities in developing countries. It highlights where investment is being focused on a regional basis.

Chapter 3 explores the role that SMEs play within clean technology industries. It highlights the portion of the clean technology opportunity accessible for SMEs and looks at different stages of the value chain that SMEs can expect to enter.

Chapters 4, 5 and 6 illustrate the opportunities quantified in Chapters 2 and 3 by probing the country and sector levels. They examine solar technologies in India, bioenergy in Kenya, and climate-smart agriculture (CSA) in both countries, and explore how local SMEs are exploiting these opportunities.

Finally, Chapter 7 provides a set of actions that for policy makers and other stakeholders to consider in supporting competitive green industries and innovative SMEs in particular.

Defining the Clean Technology Sector

Clean technology has evolved from a niche 1970s environmental aspiration into a competitive force motivating many of the world's most progressive business planners and boardroom strategists. It has also caught the attention of governments seeking to build their economies around sectors of the future, where resource efficient and low carbon technologies are expected to become everyday products and services demanded by consumers and of significant interest to investors.

CLIMATE CHANGE REPRESENTS AN OPPORTUNITY FOR DEVELOPING COUNTRIES TO BUILD LOCAL GREEN INDUSTRIES THAT CAN DRIVE SUSTAINABLE ECONOMIC GROWTH AS WELL AS ENVIRONMENTAL BENEFITS.

The concept of a "clean technology sector" has only emerged over the past decade. Climate change science and multiple environmental pressures led governments to build a policy space that encouraged more efficient, lower carbon technologies. Investors became interested in the nascent sector because of the opportunities and risks presented by forthcoming environmental policies, high energy and resource costs that made resource efficiency more economically attractive, a maturing innovation landscape that reduced clean technology costs, and a growing social appetite for cleaner production. Together, these public and private sector shifts allowed a clean technology market to emerge, which encompassed an array of products, services and processes that shared a common set of characteristics: they all delivered value using fewer resources and producing less pollution (carbon, waste or otherwise) than conventional solutions (Pernick and Wilder, 2007).

The clean technology banner has since been widely applied, although, given its relative youth, consensus on which subsectors should be included in the market has not been reached. Nevertheless, it is a market whose evolution is enthusiastically tracked by both investors and government planners who are eager to position themselves at the head of this growth-oriented sector.

5 This report uses the term "clean technology" to cover the full range of technologies that provide climate mitigation or adaptation benefits or other positive environmental benefits. A typology of these technologies and related industries is included in Chapter 2.

Technologies Covered in this Report

To stay below the internationally agreed limit of 2°C warming, low carbon technologies and practices need to be applied across the breadth of emissions sources (World Bank, 2013a). Action in all areas is important, but especially in the power sector, industry, forestry, and agriculture, which represent the four largest abatement opportunities. This report focuses on some of the sectors that provide the greatest opportunities in reducing emissions and improving resource efficiency.

The report equally focuses on technologies that offer a "sweet spot" to developing countries in that they provide economic or social co-benefits in addition to abatement potential. Renewable energy, for example, is featured heavily in this report partly because of its importance to the global abatement agenda, but also because developing countries have real, quantified policy intentions to develop renewable power generation capacity to meet energy access needs. Lower carbon transport options are also included because of their large abatement potential and their alignment with the mobility challenges faced in rapidly urbanizing developing countries. While waste offers the smallest of the abatement opportunities in absolute terms, it is included in this report because it is a large economic opportunity and is a fast-growing challenge in developing countries, as are water and sanitation (WRI, 2013).

Forestry is not profiled because it depends more on government policy than an active private sector. The market size for energy efficiency in buildings and industry is also not quantified because the data available would not allow for a robust estimation, although both the abatement potential and SME opportunity from energy efficiency are large, as described in Box 1.1.

Agriculture is critical, especially in developing countries whose populations and economies rely heavily on the sector, which is why CSA is profiled in this report. The market size of CSA opportunities that are accessible to SMEs, however, is not quantified, for reasons outlined in Chapter 5.

BOX 1.1. Energy efficiency: a big abatement and SME opportunity

While the commercial opportunities in energy efficiency are large, multifaceted, and open to SME participation, they are not profiled in greater depth in this study because of the lack of data (particularly national investment plans) needed to undertake the analysis to a comparable degree of country level granularity.

The built environment accounts for up to 30 percent of annual global emissions and up to 40 percent of energy consumption, and the industrial sector is also a major emitter (UNEP, 2009a). Energy efficient technologies and practices can significantly reduce emissions from new buildings and industrial complexes, and energy efficiency retrofits can unlock emission abatement opportunities in the highly durable existing building stock. Implementing energy efficiency is needed as old buildings and facilities are refurbished and as new ones are built to accommodate a growing and increasingly urban and industrialized global population, especially in developing-world regions where population growth, urbanization, and industrialization are happening most quickly.

Skilled construction, new materials, innovative design, and a focus on integrated resource use are all important facets of building and industrial energy efficiency. In the European Union, where energy efficiency has been a policy priority and energy costs are high, experience has shown that new green buildings and energy efficiency retrofits are well suited to SME participation since they require more tailored and bespoke interventions (Carbon Trust, 2014). Similar types of SME opportunities exist in the developing world, especially as economic growth fuels energy demand in the face of power production capacity constraints. Energy efficiency improvements can address this dilemma cost effectively (UNEP, 2014).

The overall size of these markets is undoubtedly large, including for SMEs. Some estimates put the annual energy efficiency investment need at close to $100 billion per year over a twelve-year timespan in developing regions alone if cost-effective energy efficiency opportunities are to be realized (McKinsey, 2008).

Other adaptation technologies (outside of water and wastewater treatment and purification) are not covered as the technologies and markets are not sufficiently defined for robust market sizing. However, adaptation technologies are of crucial importance particularly for the most climate-vulnerable countries. They also present good SME opportunities as countries with limited resources seek locally developed adaptation solutions. Establishing a clearer understanding of these technologies and markets presents an opportunity for future research with high value to developing countries.

In this report, the market size for 15 clean technology subsectors is estimated. The subsectors included are shown in Table 1.1.

Comparing Clean Technology with Other Technology Sectors

Different than Traditional Sectors

The size of the clean technology market, discussed in Chapter 2, shows that it is important, but comparing it to other sectors allows us to examine how clean technology differs (or is similar) to more established sectors. This comparison provides clues to how the SME experience in this emerging sector might unfold, and how governments can develop policies and strategies based on the experience of other sectors to support clean technology as it matures. Three different sectors were compared to contextualize the clean technology sector:

- Construction
- Biotechnology
- Information and communications technology (ICT)

TABLE 1.1. Clean technology sectors and subsectors covered in this report

Sector	Subsector	Inclusions and exclusions
Renewable energy technologies	• Onshore wind • Small hydro • Solar photovoltaic (PV) • Concentrated solar power (CSP) • Solar thermal • Bioenergy • Biofuels • Geothermal	**Included in market size** • Technology costs, construction and installation of equipment • Discounted operation and maintenance (O&M) for lifetime of equipment **Excluded from market size** • Transmission infrastructure
Waste, water and sanitation	• Water treatment and purification • Wastewater treatment • Municipal solid waste management	**Included in market size** • Technology costs, construction and installation of treatment facility, plus collection/transport of solid waste • Discounted O&M for lifetime of plant and equipment **Excluded from market size** • Sewers, pipes and infrastructure outside fence of treatment facility
Transport	• Electric vehicles (EVs) • Electric bikes (e-bikes) • Bus Rapid Transit (BRT) • Natural gas vehicles (NGVs)	**Included in market size** • Natural gas vehicle retrofit kit; entire EV and e-bike; buses and dedicated transit ways • Discounted O&M for lifetime of BRT **Excluded from market size** • O&M of NGVs, EVs and e-bikes

Comparing these sectors to clean technology along three themes that are particularly relevant to developing countries and SMEs—investment, innovation and jobs—further highlights the relevance of clean technology and the potential it has to drive employment, innovation, and economic growth.

Investments

Clean technology ventures have raised significant risk capital investment in developed countries, although the overall amounts are lower than either biotech or ICT. Moreover, the fraction of risk capital and R&D expenditure is modest as a proportion of overall deployment spending.

Clean technology ventures in Europe and the United States raised more than $24 billion in venture capital (VC) between 2007 and 2012 (FS-UNEP Collaborating Centre, 2013). For comparison, biotech ventures in Europe and the United States raised over $31 billion, and ICT ventures raised over $53 billion over the same period (PWC, 2013; European Private Equity and Venture Capital Association, 2012).

Global new investment in renewable energy in 2011, which totaled $244 billion, was largely asset finance[6] (for instance, investing in building a wind farm), while about 5 percent was risk capital (1 percent from VC and about 4 percent from private or government R&D). The relatively small VC investment highlights one of the challenges of investing in clean technology because of the particularly high CAPEX, long timeframes, less differentiated product, and regulation-dependent innovations. As a result, clean technology VC is more likely to be invested in energy efficiency solutions and software and services at the expense of newer technologies that continue to rely on government finance for early stage development.

The investment experience also highlights the unique characteristics of clean technology, which has greater difficulty attracting VC, and requires more public investment than traditional sectors. This investment obstacle is even more pronounced in developing countries where payback scenarios are more uncertain and SMEs and new ventures are riskier.

6 Asset finance refers to all money invested in renewable energy generation projects (excluding large hydro), whether from internal company balance sheets, from loans, or from equity capital.

Innovation

Clean technology is a particularly fertile area for innovation since it is defined as any product, service, or process that delivers value using fewer resources and producing less pollution (carbon, waste, or otherwise) than conventional solutions. Essentially, any innovative improvement that results in a greener outcome would fall under the clean technology umbrella. Innovation is the lifeblood of this sector, but illustrating that intrinsic connection with hard data can be challenging. Nevertheless, some indicators like patents are helpful.

OECD data shows environmental technologies account for a significant proportion of patent applications globally. There were 10,286 environmental technology Patent Cooperation Treaty (PCT) applications filed in 2010, representing 6 percent of total PCT filings globally in 2010 (the latest data available from OECD). This is similar to the biotech industry (also 6 percent), and more than the construction industry (3 percent) and mining industry (1 percent) combined. The ICT sector dominates PCT filings though, with about 35 percent of applications in 2010 (OECD, 2011).

Environmental technology patents grew at a compound annual rate of 9 percent from 1999 to 2010 (based on PCT filings), which is second only to the mining sector in terms of growth rate (10 percent) but for a significantly higher number of patents (OECD, 2011).

Jobs

Looked at through the lens of job creation, clean technology is impressive in the developed world. U.S. employment in clean technology represents 2.6 percent of the total workforce, supporting over 2.5 million private sector and 886,000 public sector jobs (U.S. Bureau of Labor Statistics, 2013a). That is more than in educational services, at about 3.2 million; about one-third of America's employment in manufacturing, at 11.5 million; or 40 percent of the financial services sector, at 7.8 million (U.S. Bureau of Labor Statistics, 2013b). Germany has about 2 million people employed in the clean technology sector, almost 5 percent of its total workforce (European Employment Observatory, 2013). For comparison, Germany's automotive industry, one of the country's largest employers and one of the engines of its industrial production, employs about 742,000 people (Verband der Automobil Industrie, 2013). German biotech employs just over 35,000 people (Biotechnologie.

Photo: Dana Smillie / World Bank.

de, 2013). In the United Kingdom, about 940,000 people are employed in clean technology, compared to about 213,000 in telecommunications (U.K. BIS, 2013; Green Alliance, 2012). Against these benchmarks, it is clear that clean technology is a major employer.

Clean technology jobs also compare favorably to jobs in other sectors: green jobs tend to be more skilled, safer, and better paid than jobs in similar sectors. Indeed, the move towards a lower carbon, more resource-efficient economy is expected to yield a double-dividend in terms of employment and environmental improvement. The International Labour Organization (ILO) estimates that transitioning to a greener economy could yield a net gain of 60 million jobs (ILO, 2013).

Conclusion

Climate change presents a formidable challenge to developing countries. However, climate change also presents an opportunity. In the developed world, SMEs are crucial in driving clean technology innovation and activity, and evidence suggests SMEs in emerging economies can follow suit if supported by appropriate government policies and support structures to help them take advantage of the lucrative opportunities that exist.

The clean technology sector has unique characteristics that, for instance, limit private risk capital investments and suggest a greater role for public finance in supporting early stage companies. However, the clean technology sector as a whole compares favorably to other sectors on innovation output and job creation and quality. Countries that successfully build local green industries can capture this economic value while simultaneously building climate resilience.

Chapter 2

Sizing Climate and Clean Technology Markets

Main Points

- Clean technology is a huge global market. In 2011/2012 the sector was a $5.5 trillion global market and it is currently forecast to grow at around 4.1 percent annually until 2015/2016, significantly faster than the global economy.
- Clean technology investment in developing countries is quickly catching up with investment in developed countries. In 2012, clean technology investment rose by 19 percent in developing countries compared with an overall decline of 12 percent globally, suggesting that clean technology investment is shifting towards developing economies in the near term.
- Investment across 15 clean technology sectors in 145 developing countries is expected to top $6.4 trillion over the next decade, with $1.6 trillion of that market accessible to SMEs.
- Investment in wastewater treatment facilities represents over a third of the total likely clean technology investment in developing countries (about $2.7 trillion), with water treatment, onshore wind power, solar PV, small hydro and waste management the next largest sectors (each between about $300-800 billion). Renewables should attract about $2 trillion in investment.
- Regionally, about $1.5 trillion will be invested in China, and slightly less will be invested in Latin America and the Caribbean. Roughly $900 billion will be invested in each of Sub-Saharan Africa, Asia (excluding China and India) and North Africa and the Middle East; $440 billion will be invested in India, and $235 billion in Russian and Middle Income Europe.


Photo: Dave Lawrence / World Bank.

Photo: © Simone D. McCourtie / World Bank.

The Global Clean Technology Market

The global clean technology market was valued at approximately $5.5 trillion[7] in 2012 (U.K. BIS, 2013), comparable to the global construction industry, which had a global turnover in 2013 of $7.0 trillion.[8]

Clean technology is also a fast growing sector whose growth is not only accelerating, but whose projected growth is regularly revised upwards;[9] a 2012 German government study (DE BMU, 2012) predicted the market would double by the mid-2020s. The global clean technology market is forecast to grow at around 4.1 percent annually until 2015/2016 according to U.K. BIS (2013), which significantly outstrips global average economic growth projections of 2.2 percent to 3.3 percent over the same period by the World Bank (2013b).[10] By contrast, the global automotive industry is forecast to grow at 3.8 percent per year over the same time period (McKinsey, 2013a).

FIGURE 2.1. Growth in global clean technology sales 2007-2012 (in $ trillion)

Source: U.K. BIS (2013).

Breaking down the clean technology market into its constituent subsectors shows which areas are driving this performance. The top six subsectors in terms of global market size are alternative fuels,[11] building technologies, wind power, alternative fuel vehicles,[12] geothermal, and water supply and wastewater treatment. Across the board, low carbon and renewable energy, water and sanitation, waste management solutions, and cleaner mobility make up the bulk of the market (see Figure 2.2).

7 According to a U.K. Department for Business, Innovation and Skills (BIS) 2013 report, the total sales for the Low Carbon Environmental Goods and Services (LCEGS) sector in 2011/2012 was £3.4 trillion. This was converted to $5.5 trillion using an average exchange rate of $1.00 /£1.5847 for the year 2012 and uplifted to 2013 price from assumed 2012 price levels using an average inflation rate of 1.5 percent. Historical exchange rate was obtained from www.oanda.com, and the U.S. annual inflation rates were obtained from U.S. Department of Labor, Bureau of Labor Statistics.

8 According to the Confederation of International Contractors' Associations website: http://www.cicanet.com/

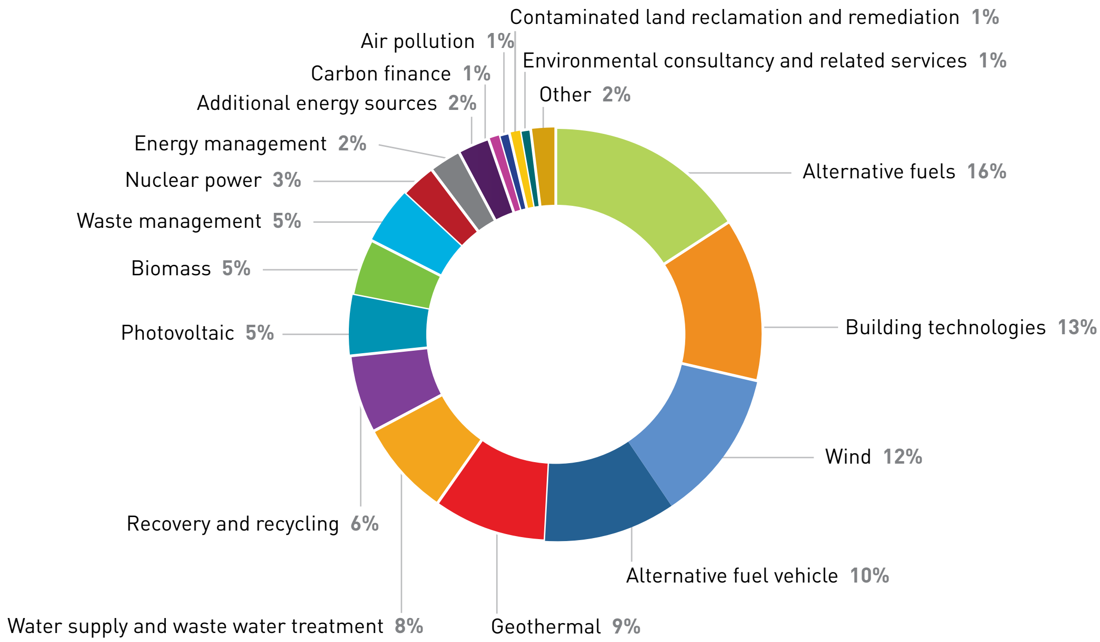
9 The upward revision was documented in U.K. BIS reports in 2011, 2012, and 2013.

10 The Climate Group also conducted a market sizing exercise and estimated the global clean technology market to be worth more than $2.56 trillion a year, and is expected to be valued at more than $5.13 trillion by the mid-2020s. They found the market to be growing at 12 percent a year since 2007. The overall size and growth rate is different from the U.K. BIS estimate because the subsectors included in each report differ.

11 Alternative fuels include the manufacture, production, supply, and distribution of: batteries, biodiesel, butanol, ethanol, vegetable oils, biomass, methane, peanut oil, vegetable oil, wood and woodgas, and hydrogen.

12 Alternative fuel vehicles includes production, supply and distribution of natural gas, synthetic fuel and auto gas, RD&D for hydrogen fuel cells and hydrogen internal combustion, electric, hybrid electric, steam powered, organic waste fuel, wood gas, solar powered and air, spring and wind powered vehicles.

FIGURE 2.2. Global clean technology sales breakdown, 2011/12



Source: U.K. BIS (2013).

Market Size in the Developing World

The gap in clean technology investment between developed and developing economies is shrinking significantly; at the end of 2012 it stood at 18 percent ($132 billion versus $112 billion per year). This gap is down from 250 percent in 2007, according to Forbury Investment Network (2013). The same report cites that in 2012 alone, clean technology investment rose by 19 percent in developing countries compared with an overall decline of 12 percent globally, suggesting that clean technology investment is shifting towards developing economies in the near term.

This trend is unsurprising given that developing countries face growing pressure to increase their energy supply—in quantity, reliability, and affordability—while simultaneously increasing the clean share of their energy mix to decrease their emissions and mitigate climate change. This double challenge is particularly acute in low-income countries where people still lack access to basic energy services, and where long-term environmental benefits are difficult to favor over demands for access to affordable energy.

Similar pressures exist in other clean technology sectors that seek to provide basic services to people in a more efficient, affordable, and clean manner. The investment figures suggest that developing countries are rising to the challenge and investing in transforming environmental and climate change challenges into market opportunities.

The Methodology for Sizing Developing Country Markets

Much of the existing literature has been devoted to understanding the dynamics of the clean technology market in the developed world. Similarly, while there is fairly comprehensive data on the size and value of clean technology markets at a global or regional level, its coverage is focused on the developed world and a few large emerging economies such as China.

Clean technology markets in the developing world are less well understood and suffer from a lack of country-level granularity; it is not uncommon for assessments of the entire African market to be based on a handful of the larger of its 54 country economies, or for Africa to be ignored altogether in important sectors like solid waste or clean road transport. What coverage there is focuses on large-scale renewables (for instance, wind, solar, geothermal) and not on the other clean technology sectors that are also highly relevant to SMEs.

This report closes that gap through a regional analysis of 15 clean technology markets in 145 countries over the next decade. In order to cope with these data limitations, the methodology was designed to make use of existing data and projections, coupled with clear assumptions to allow for estimates of the addressable market for local SMEs, at regional and sectoral levels.[13]

This research is unique in two ways: because of the regional granularity underlying the market size analysis, and because the market forecasts are based on planned investment rather than needed investment. This report's regional granularity is stronger than most research because the methodology extrapolated to data-poor countries using subregional groups (for instance, four African subgroupings) rather than using traditional regional groups that rely on geographic borders rather than other indicators that are relevant to likely future investment (for instance, GDP/per capita or ease of doing business factors).

Moreover, this research does not reflect possible or needed investment like many studies do, but rather outlines investments that are actually expected to be made in these regions over the next decade, based both on current government policies and plans, and on careful extrapolation to nearby countries with similar policies and resource availability.

The SME opportunities, therefore, are not based on broad-brush continental aspirations, but on regional evidence that deconstructs planned investment into a segmented value chain analysis. By illustrating the developing-world clean technology opportunity in this way, this chapter aims to provide governments and agencies with evidence that can help them to promote the realization of these opportunities through policies and programs of entrepreneurial support that target the areas of high value.

Market Size of Clean Technology Sector in Developing Countries

The fifteen clean technology subsectors are likely to attract $6.4 trillion over the next decade ($1.6 trillion accessible to SMEs) in the countries examined, with considerable additional investment expected in the sectors not covered in depth by this report (see Figure 2.3). Even when excluding China, India, Russia, and Middle Income Europe, these opportunities are still significant: $4.1 trillion overall, of which $1.0 trillion is accessible to SMEs.

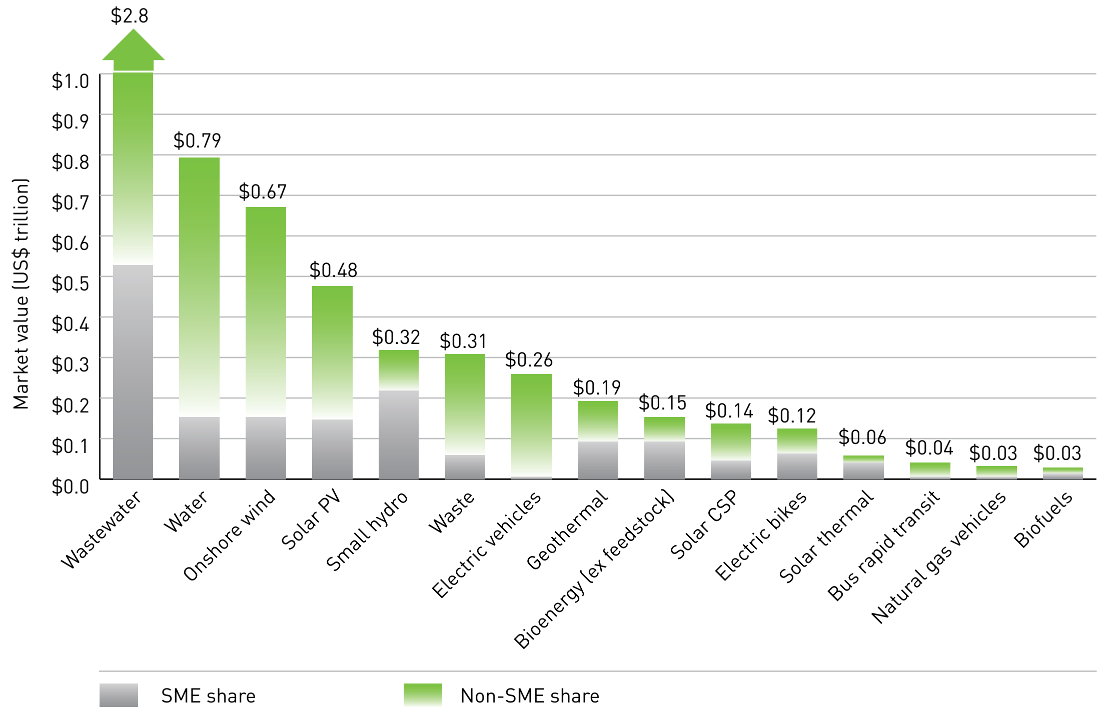
Over the next decade, it is estimated that renewable energy deployment in 145 developing countries could attract just over $2 trillion of investment. This would be the result of a policy and regulatory environment that supports renewable deployment, fast-growing energy demand along with falling renewable energy costs, and available local natural resources.

Water, wastewater, and solid waste management would also require major investment of up to $3.9 trillion over the next decade. As countries enjoy growing national prosperity, investment in public services, especially water and sanitation, is expected to be a priority. Now, wastewater

Photo: World Bank.

13 The market sizing methodology is described in Appendix A. Full details of the market sizing may be requested from the authors.

FIGURE 2.3. Market size through 2023 for 15 clean technologies in developing countries ($ trillion)



Source: Authors' analysis.

treatment[14] is increasingly becoming a public priority as waterways grow polluted and water scarcity becomes a more salient issue. Investment in the construction and operation of these systems would come from the government or through a public-private partnership, and would be administered by water and wastewater treatment companies, including their suppliers, among whom would be SMEs.

Solid waste management[15] is also a growing priority. In densely populated urban areas, soaring waste volumes require organized public attention, and while solutions like waste-to-energy are gaining popularity, in poorer countries the majority of low-cost, sanitary disposal continues to be landfilling. In this report, sanitary landfills are considered to be clean technology compared with the most common alternative—open dumping—which carries a much greater ecological cost. Consolidating waste in landfill also enables landfill gas recovery, a low carbon energy generation technology, to be deployed.

Lower-carbon transportation is a smaller but still significant market, worth up to $456 billion over the next decade. These sectors often attract investment because of their co-benefits rather than because of their environmental outcomes. Bus Rapid Transit has proven to be an effective way of transporting a lot of people from suburban areas and through increasingly crowded urban centers with relatively low upfront capital cost, and are being built to accommodate swelling urban populations. Vehicles powered by natural gas are more cost-competitive than gasoline and diesel vehicles in many markets and generate significantly less carbon emissions. Electric vehicles are strongly supported by the governments of India and China, and Chinese consumers are leading the way in adopting electric bikes.

14 In this report, the market size for water and wastewater includes the CAPEX and operating costs that are inside the fence of the treatment facility itself. So filtration and purification systems, cesspools, dewatering equipment, holding tanks, internal piping, and treatment chemicals would be included, whereas municipal sewage systems and freshwater pipes and pumps would be excluded.

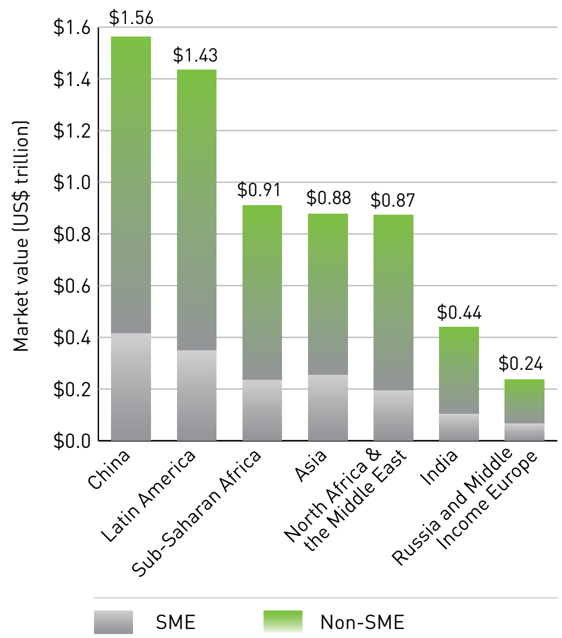
15 The market size for solid waste has two dimensions: collection (the costs of trucks and operating labor) and treatment (CAPEX and O&M related to landfill construction, operation, and decommissioning).

The Regional Picture

The regional opportunities are diverse and highly driven by both natural resource endowments and government policy priorities. While investment is large and growing throughout the developing world, China and Latin America stand out as leaders (see Figure 2.4).

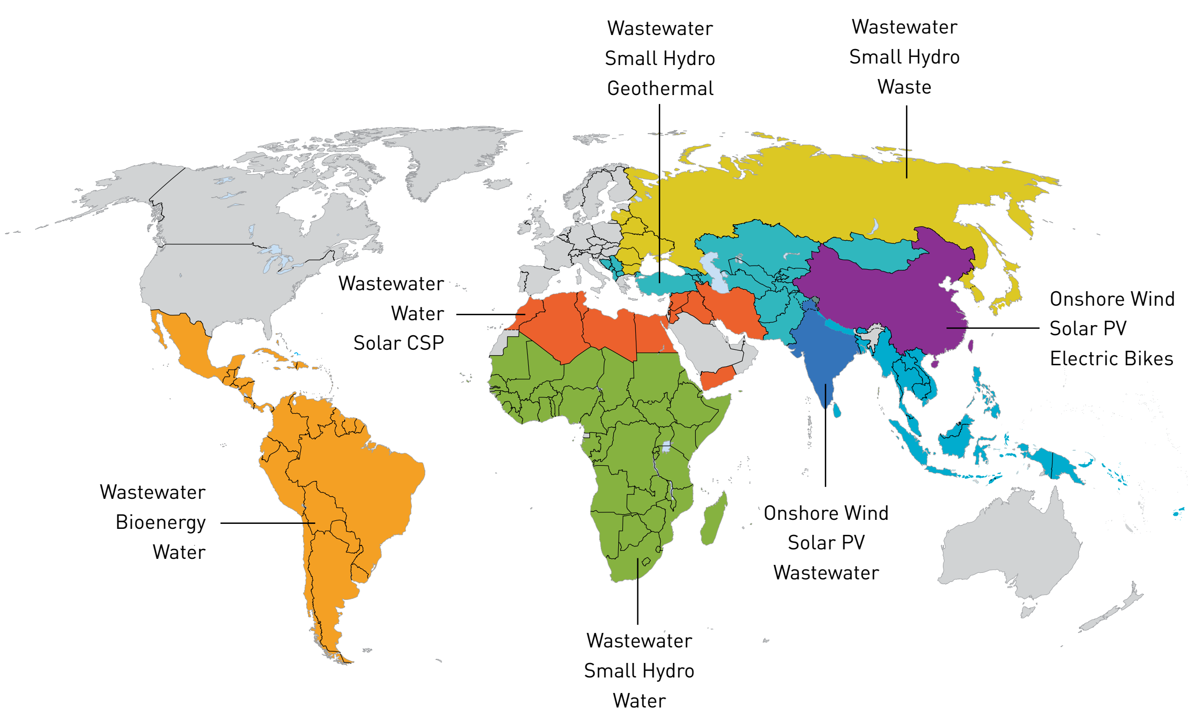
Wastewater features in the top three opportunities for SMEs across the entire developing world, with the exception of China. Countries are investing heavily in wastewater infrastructure and services to provide basic services to their growing populations while ensuring a stable water supply to grow industries reliant on water use. A number of the renewable and nonrenewable technologies are also expected to present significant opportunities for SMEs as well and they are each discussed in turn with the top three opportunities for each region highlighted in Figure 2.5.

FIGURE 2.4.Clean technology market size by region, and the shares of SMEs and non-SME ($ trillion)



Source: Authors' analysis.

FIGURE 2.5. Top three regional opportunities for SMEs



Source: Authors' analysis.

Latin America

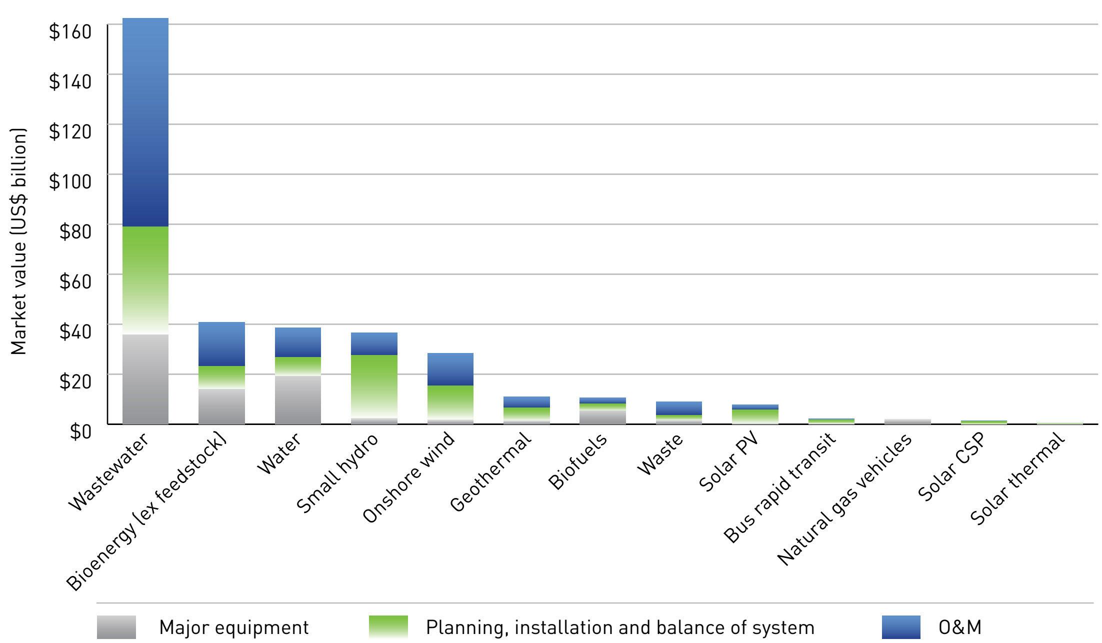
The leading opportunities for Latin American SMEs are in wastewater (about $160 billion), bioenergy (about $40 billion), and water (about $40 billion) (see Figure 2.6). Within the region some countries are seeing fast growth. The Inter-American Development Bank (2013) reports that five countries experienced triple digit growth in clean technology investment in 2012: Mexico (450 percent), the Dominican Republic (431 percent), Uruguay (327 percent), Peru (325 percent), and Chile (314 percent).

The lack of current wastewater treatment threatening regional water sustainability is driving investment in the region. Currently only 20 percent of Latin America's wastewater is treated, explaining recent large government investments (BN Americas, 2013). For example, the Brazilian government is investing heavily in water, wastewater, and sewage treatment facilities (Carbon Trust, 2012a). New and upgraded infrastructure is being financed through Phase 2 of Brazil's National Growth Acceleration Program (PAC2) and this will see the deployment of water and wastewater solutions at an enormous speed and scale (Carbon Trust, 2012a). Peru is also prioritizing the sector and has committed to raise wastewater treatment levels from 15 percent in 2010 to 100 percent by 2015 (Sanitation Updates, 2010).

While it is not likely that SMEs will capture a large share of the wastewater market value across the value chain, the overall scale of investment required in the sector to meet government targets creates a large opportunity (that is, SMEs can access a small portion (about 20 percent) of a large market ($160 billion)). The need for ongoing operational inputs, such as chemicals, polymers and filters are niche SME opportunities and areas for innovation. For example, specific flocculating agents are added to wastewater pools to enhance the aggregation of suspended particles, which accelerates wastewater separation and can enhance the efficiency of the dewatering process. These opportunities are an example of potential ongoing income streams generated by wastewater activity that are available to SMEs in this sector.

Bioenergy presents a large opportunity for SMEs across the value chain in Latin America. The region has great bioenergy potential, with a land area of around 250 million hectares available for feedstock production, led by Brazil (Inter-American Network of Academies of Science, 2012). Ethanol production is poised to grow enormously over the next ten

FIGURE 2.6. Size of the clean technology market accessible to SMEs in Latin America ($ billion)



Source: Authors' analysis.

years, and heat and electricity from biomass, especially from sugarcane bagasse, is also primed for significant growth (Carbon Trust, 2012a).

All new mills in Brazil are now equipped with cogeneration equipment that produces heat and electricity. Newer cogeneration equipment is more efficient, which has allowed mills to sell on the excess electricity (this can be up to 30 percent of revenue for new mills) (Carbon Trust, 2012a). Forecasts estimate that newly built mills and refurbished older ones will see power production increase to between 9 and 13 GW by 2020 (Carbon Trust, 2012a). Examples of potential SME activities in bioenergy are found throughout the value chain, but are most abundant in operations and maintenance, specifically around planning and feasibility consultancy, ash disposal, and component and equipment maintenance.

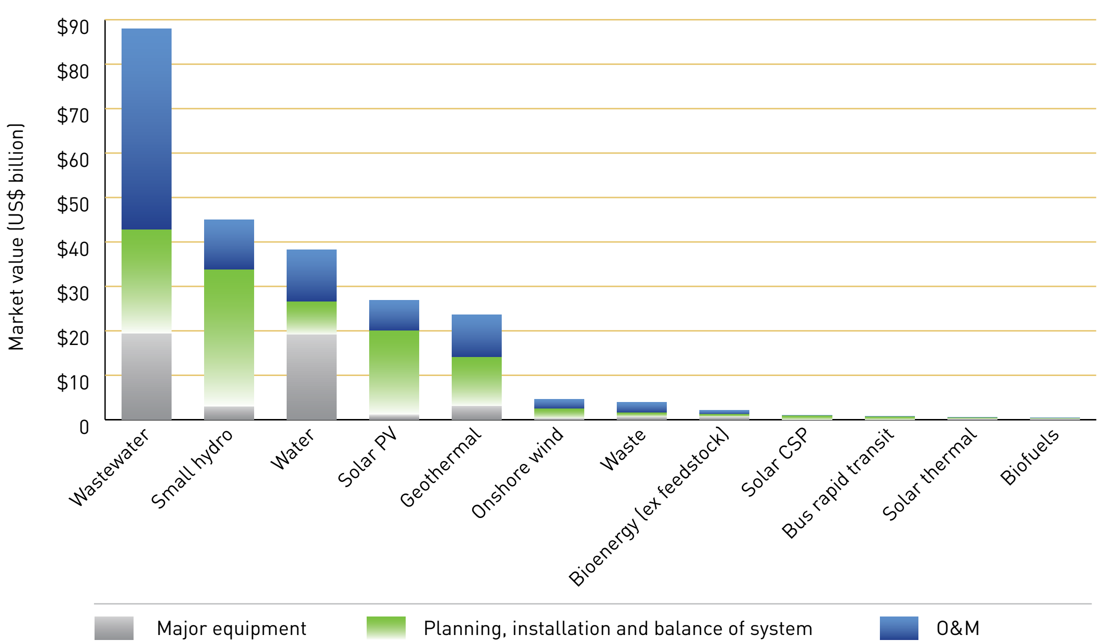
Sub-Saharan Africa

The leading opportunities for Sub-Saharan African SMEs are in wastewater (about $90 billion), small hydro (about $43 billion), and water (about $40 billion) (see Figure 2.8). Solar PV and geothermal are also large potential markets worth between $20 billion and $30 billion to SMEs.

The drive to achieve the Millennium Development Goals (MDGs) in wastewater and water in Africa would fuel investment and SME opportunities. Wastewater and water is a priority for investment in Africa. Both markets are driven by investment by donors and governments. The largest opportunities in wastewater are in West and Central Africa (about $41 billion), followed by Southern Africa (about $32 billion).

Growth in wastewater investment however is not solely driven by public investment; a significant portion of the market growth will be driven by increased wastewater treatment activities from fast growing mining activities in the region that are now subject to more stringent environmental regulations (25 Degrees in Africa, 2011). There is also increased pressure on countries to take a more integrated approach to their water and waste management activities, particularly in the fast growing urban areas across the continent. SMEs active in the sector that are able to deliver solutions that look at the system as a whole rather than in isolation will be particularly well placed. Similar to wastewater, the water sector has a number of promising SME activities both in urban and rural areas. SME opportunities include the supply of pressure and leakage management equipment, and filtration and advanced treatment

FIGURE 2.7. Size of the clean technology market accessible to SMEs in Sub-Saharan Africa ($ billion)



Source: Authors' analysis.

membranes, both part of the balance of systems segment of the value chain. Modeling of distribution and collection networks, and water flow monitoring, are also opportunities.

An example of an SME active in this space is Smart Leak Detection Company, based in South Africa. It offers water leak detection services for municipal infrastructure, and commercial and residential clients. Infrared radiometric pipeline testing can identify subsurface pipeline leaks, deteriorated pipeline insulation, poor backfill or voids caused by erosion. The technology detects differences in thermal conductance caused by a water leak plume compared to dry soil or backfill, and can help municipalities save money, water, and energy by identifying leaks without first having to excavate buried pipes. The company sources some of its equipment from other South African suppliers, like Sewerin, a maker of water and gas leak detection systems.

Demand for small hydro projects in East Africa would address rural electrification needs and this sector is well suited to SMEs. East Africa is leading the way in small hydro opportunities with about $38 billion of the $43 billion regional SME opportunity, in part because of the numerous small rivers that run through the region. Small hydro provides large opportunities for SMEs in the balance of systems and operation and maintenance segments of the value chain. The low upfront capital requirements for making small hydro systems means that SMEs could also realistically capture about 25 percent of the major components segment of the value chain. Small hydro also has significant development benefits as it offers the potential for electrification of isolated and rural areas, and provides local small business the energy needed to upscale (Consultancy Africa Intelligence, 2012). East African Governments have taken notice of the small hydro opportunity. In Uganda and Rwanda, programs have been developed to target private investment in small hydro projects; Uganda has already introduced 30MW into the grid using privately financed projects (Consultancy Africa Intelligence, 2012).

Small-scale hydropower projects are, by their nature, suitable for identification and development by SMEs. Scouting for appropriate sites, getting local consent for construction, connecting rural

Photo: *info*Dev

populations with mini-grids, and designing bespoke systems are all activities that are more suited to SMEs than large power companies. Micro-hydro projects can even be owned and managed by a local community cooperative, rather than a corporate power provider. For instance, Tungu-Kabiri community micro-hydro power project in Kenya is community-owned. The project involved the construction of a small weir, canal and penstock, which diverts river water to an 18kW turbine, supplying electricity to a small community through a micro-grid (Energize, 2012). This can unlock design, construction, and operations activities for SMEs, especially since many of the system components of a small hydro facility do not require advanced technology (Microhydropower.net, 2013).

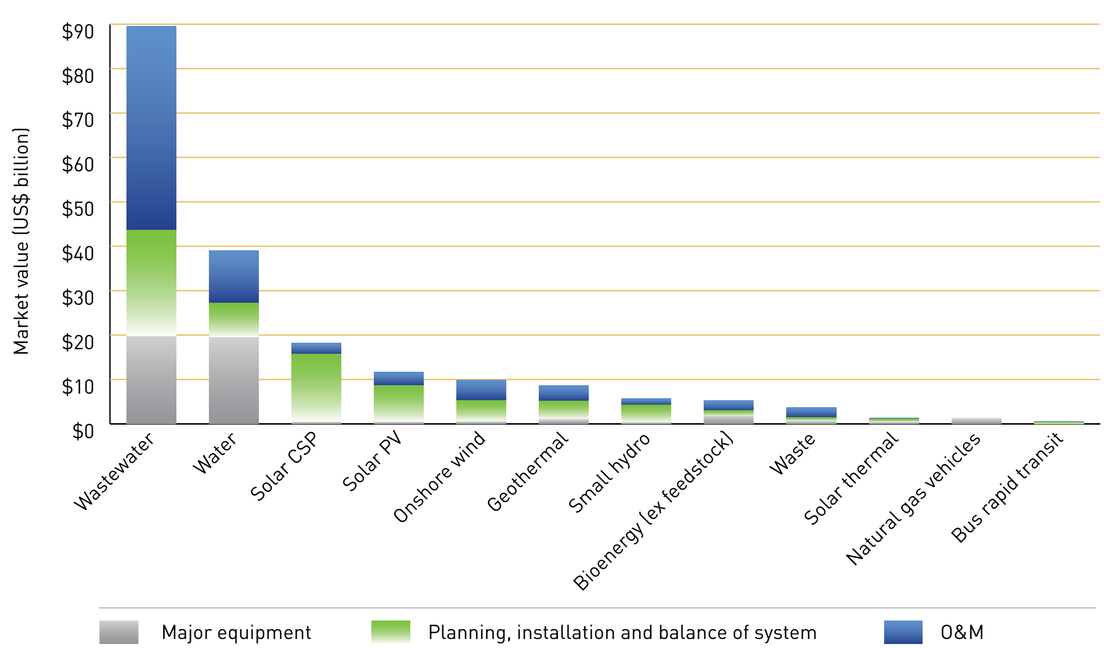
Middle East & North Africa

The leading opportunities for North African and Middle Eastern SMEs are in wastewater (about $90 billion), water (about $40 billion), and CSP about ($20 billion) (see Figure 2.8).

Given the region's arid climate, it is unsurprising that investment in wastewater and water solutions dominate the clean technology opportunity space. Treating wastewater properly means it can be used and re-used both for commercial purposes and for drinking consumption. Not treating it means it either gets used in an unsanitary way or does not get used at all. Water treatment and purification is also a growing sector as the region's population grows and water demand increases.

Solar technology represents a significant opportunity in the region. This is the only region where the size of the CSP opportunity exceeds that of solar PV. The region's clear, sunny skies make it ideal for CSP technology, which needs direct sunlight to work, unlike solar PV which still operates in cloudy conditions. This region is one of several global hotspots for solar resource, receiving over 3,000 kWh/m^2/year, as much as parts of Australia, the Nevada desert, and areas on the leeward side of Chile's mountain ranges. This abundant resource could eventually be exported via high-voltage subsea interconnection cables that link North Africa to European markets, although such plans are more visionary than concrete at present (PWC, 2010). Both types of solar, however, offer large regional opportunities.

FIGURE 2.8. Size of the clean tech market accessible to SMEs in the Middle East & North Africa ($ billion)



Source: Authors' analysis.

Asia (Excluding China and India)

The leading opportunities for Asian SMEs are in wastewater (about $85 billion), small hydro (about $50 billion), and geothermal (about $48 billion) (see Figure 2.9). The main drivers for increasing investment in wastewater collection and treatment, and water treatment in Asia are the rapid growth of urban areas and also the increase in thermal power generation, as some Asian countries drastically increase their coal generation capacity and will need water treatment facilities. One such SME taking advantage of the investment in water and wastewater treatment in Indonesia is Sinar Tirta Bening. The company, founded in 1998, provides a range of services to companies including procurement, design, and build systems for clean water and sewage water treatment systems.

The Pacific Ring of Fire makes geothermal power a viable natural resource for several Southeast Asian countries and island states. The region's strong geothermal investment potential largely reflects the Indonesian government's ambitious plans. Indonesia enjoys about 40 percent of the world's total potential geothermal resources because of its location on some of the most volcanically active sections of the Pacific Ring of Fire (McKinsey Global Institute, 2012). In 2010, the government increased its 2006 goal of 9.5 GW of installed geothermal capacity by 2025 to 12.3 GW, with near-term plans to deploy around 4 GW of new capacity by 2014 (IEA, 2011). Other nearby countries with a strong geothermal natural resource, such as the Philippines, could develop ambitious plans as well.

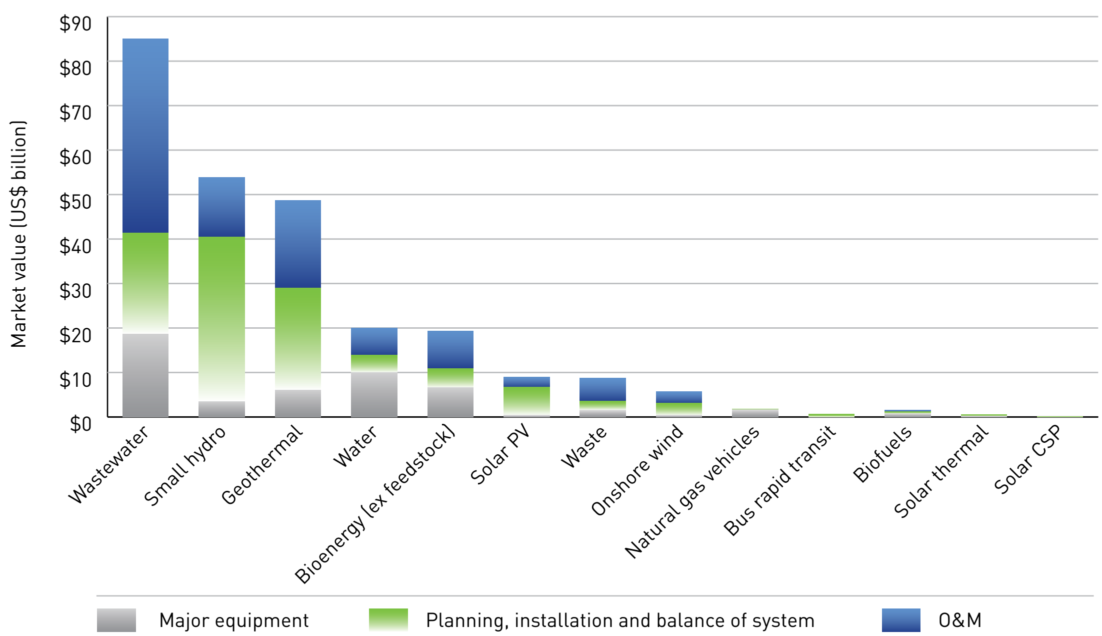
KCT, an Indonesian SME formed in 1992, is highly active in the country's growing geothermal sector. KCT supplies and leases equipment (heavy and utility) and provides other services for the geothermal industry. KCT started its operation for Unocal Geothermal Indonesia, providing equipment rentals, welding services, and supply of both skilled and unskilled labor for the Gunung Salak Operation in West Java (KCT, 2014).

Russia and Middle Income Europe

The report covers a number of middle-income countries in Eastern Europe and also Russia. The leading opportunities for SMEs in this region are in wastewater (about $30 billion), small hydro (about $29 billion), and waste (about $34 billion) (see Figure 2.10).

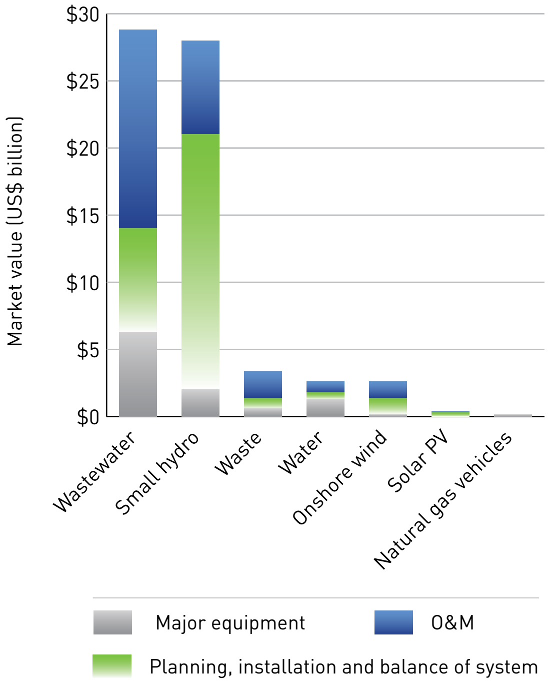
Small hydro is a particularly prominent opportunity in Romania and Bulgaria, which have hundreds of megawatts of untapped hydrological resources.

FIGURE 2.9. Size of the clean technology market accessible to SMEs in Asia, excluding China and India ($ billion)



Source: Authors' analysis.

FIGURE 2.10. Size of the clean technology market accessible to SMEs in Eastern & Northern Europe ($ billion)



Source: Authors' analysis.

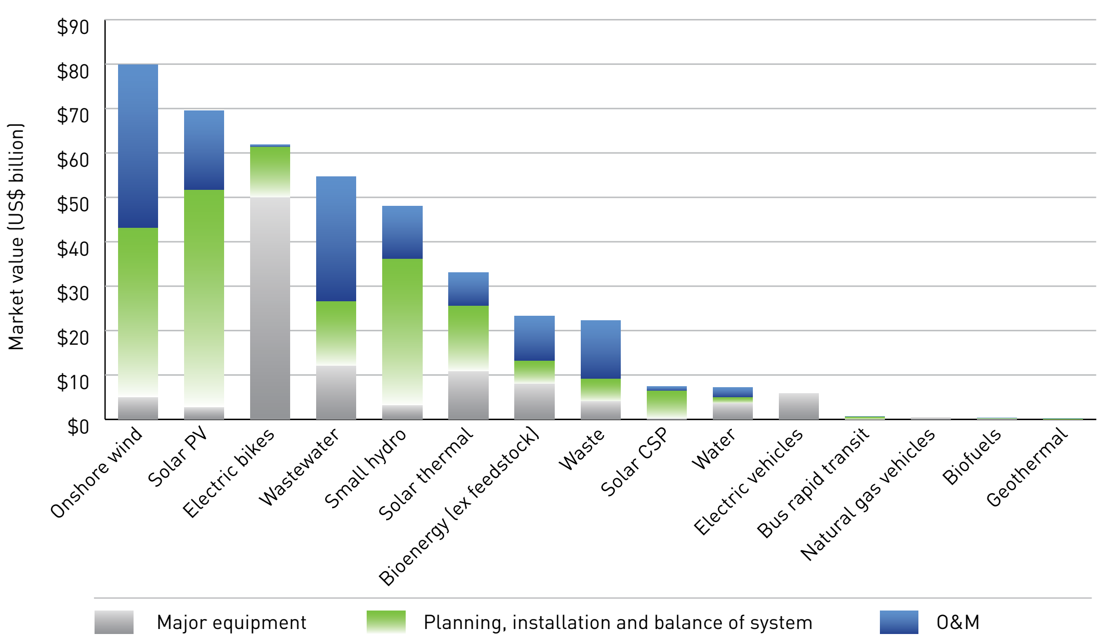
Small hydro also tends to be an inherently local activity. Onsite planning, site design, hydrological surveys and environmental impact assessments can often be carried out cost effectively by local firms with knowledge and experience regarding domestic regulatory requirements and approvals processes. The relatively small scale of small hydro activities also helps open them up to SME participation, since the capital and workforce required is relatively small.

In Bulgaria, HEC is an SME that invests in, develops, and implements integrated turnkey projects in the renewable energy sector. Their core area of focus is small hydro power plants. Their expertise is particularly strong in the construction of hydro power plants and hydrotechnical equipment. In 2007 they also expanded their portfolio of services to include PV power plants (HEC Partners, 2014).

China

Because of its size, data availability, and uniqueness, China is treated as a region on its own. The leading opportunities for Chinese SMEs are in onshore wind (about $80 billion), solar PV (about $70 billion), and electric bikes (about $63 billion) (see Figure 2.11).

FIGURE 2.11. Size of the clean technology market accessible to SMEs in China ($ billion)



Source: Authors' analysis.

The strength of the electric bike market in China makes it an outlier compared with other regions. China has a strong tradition of cycling as a common mode of transport. The introduction of electric bikes that are accessibly priced for an increasingly wealthy population, and which enable longer distance travel on roads that are increasingly navigable, are accelerating the deployment of this technology. Over the decade between 2012 and 2022, over 450,000 e-bikes could be sold (assuming they are replaced after a seven year lifespan), which makes China the undisputed global leader in this mode of transport. The major equipment component of e-bikes is also considered to be fairly accessible to SMEs.

While electric vehicles do not appear to be a large opportunity compared with other clean technology sectors, China nevertheless leads the countries in this report with ambitious deployment plans endorsed by the state. These two sectors illustrate the degree to which China is adopting low carbon mobility.

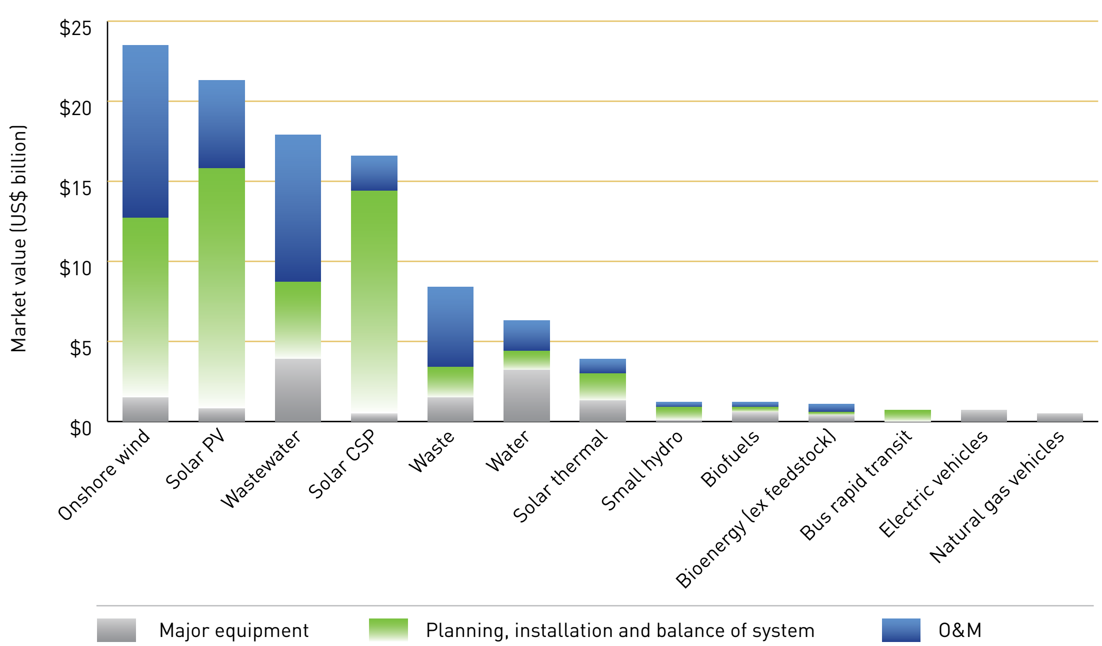
China's deployment plans for onshore wind and solar PV are also driving an enormous amount of investment. China's global market share of solar PV production grew from less than 2 percent in 2002 to 45 percent in 2010 (Sahoo and Shrimaliy, 2013). The government's institutionally coordinated industrial PV strategy has helped develop a strong domestic manufacturing base, and domestic innovation, targeted subsidies, and lower-cost government loans have enabled manufacturers to thrive while cutting costs through process innovations. According to Bloomberg News (2012), solar PV costs have fallen by 80 percent since 2008, which has given the government confidence to boost its deployment targets to 50 GW installed capacity by 2020, and to further support its domestic industry. As a result, solar PV continues to present a large opportunity in China.

India

The clean technology market opportunity analysis shows that as much as $103 billion will be invested across 13 clean technology sectors in India over the next decade. The leading opportunities for Indian SMEs are in onshore wind (about $23 billion), solar PV (about $21 billion), and wastewater (about $18 billion) (see Figure 2.12).

India's response to its rapidly growing energy demand, concerns about energy security, and a desire to reduce greenhouse gas emissions have directed investment towards domestic renewable

FIGURE 2.12. Size of the clean technology market accessible to SMEs in India ($ billion)



Source: Authors' analysis.

energy sources. India enjoys among the world's highest insolation rates as well as clear, sunny skies, which makes it ideal for both solar PV and CSP. The falling prices of onshore wind and PV have also made those technologies economically competitive with other fuels. Chapter 3 examines in detail the clean technology market and policy environment in India, and focuses in particular on the solar industry and opportunities for SMEs in that sector.

India's installed wind capacity is forecast to approach 60 GW by 2020, up from about 18 GW in 2012 (GWEC, 2012, 2013). The country also plans to deploy up to 22 GW of solar power by 2022 as part of its National Solar Mission (Ministry of New and Renewable Energy-India, 2012a). These energy investments are creating significant opportunities for SMEs, especially in planning, installation, and balance of systems, and O&M segment of the value chain.

As with most other regions, water, wastewater treatment, and solid waste management are all significant opportunities since hundreds of millions of Indians lack access to basic water and sanitation services. Government programs are aiming to accelerate the deployment of these important public services. Netsol Water Solutions PVT, for example, is an Indian SME established in 2006 working across the water, and wastewater sector offering reverse osmosis systems, effluent treatment plants, and sewage treatment plants.

Conclusion

Significant investment in clean technology is planned for the developing world, which is expected to reach $6.4 trillion over the next decade, with $1.6 trillion of that market accessible to SMEs.

These investments are happening across the developing world. Regionally, about $1.5 trillion will be invested in China, and slightly less will be invested in Latin America and the Caribbean. Roughly $900 billion will be invested in each of Sub-Saharan Africa, Asia (excluding China and India), and North Africa and the Middle East; $440 billion will be invested in India, and $235 billion in Russian and Middle Income Europe.

These clean technology investments are also diverse and go beyond renewable energy. Investment in wastewater treatment facilities represents over a third of the total likely clean technology investment in developing countries (about $2.7 trillion), with water treatment, onshore wind power, solar PV, small hydro, and waste management the next largest sectors (each between about $300 billion and $800 billion). Renewables should attract about $2 trillion in investment.

This investment will create substantial opportunities for entrepreneurs and SMEs seeking to develop new businesses or expand existing ones. In the next chapter, the role of SMEs in clean technology is explored in greater detail.

Chapter 3

The Role of SMEs in Climate and Clean Technology Industries

Main Points

- The clean technology sector's size and growth prospects make it attractive for SMEs, but it is not without challenges: failure rates are high, capital requirements are a barrier, reliance on government policy is a risk, and the technical and commercial capacity required of clean technology SMEs can be a challenge.
- SMEs are most able to access opportunities in the middle segment of the value chain (including balance of systems components, installation, engineering, procurement and construction) and the final segment (O&M). Opportunities in the first segment (major equipment manufacturing) are less accessible but still possible.
- This chapter explores the opportunities and challenges clean technology SMEs face and where in the value chain large commercial opportunities for SMEs are most likely to be found.

Investment in Clean Technology Means Opportunities for SMEs

SMEs are well positioned to participate in future clean technology markets in the developing world. SMEs play an instrumental (but often under-recognized) role in furthering growth, innovation, and development, which coupled with a growing clean technology sector, can help build prosperity in the poorest countries.

Clean technology markets are well suited to SMEs. For example, it is estimated that SMEs make up over 90 percent of clean technology businesses in the United Kingdom, which compares similarly to other sectors like ICT (U.K. BIS, 2010) or biotechnology (Biotechnology Industry Organisation, 2011) but differs from industries like mining where large companies dominate (ICMM, 2012). Nevertheless, failure rates are high, capital requirements are a barrier, reliance on government policy is a risk, and the technical and commercial capacity required of clean technology SMEs can be a challenge.

Despite rich opportunities for SMEs in clean technology markets, many businesses still fail. While there are no definitive statistics on clean technology failure rates, clean technology SMEs probably have failure rates comparable to SMEs in the ICT and biotech sectors, which experience 80-90 percent failure rates. Failure rates are lower in more established industries like construction, where, for example, 64 percent of construction firms in the United States fail within 5 years (Small Business Trends, 2012).

High capital requirements can also be a barrier to SMEs, especially those looking to be involved in the design or manufacture of major equipment. Accessing opportunities in the later stages of the value chain (minor equipment manufacturing, installation, civil works, and operations and maintenance) tends to require less upfront capital. Even so, raising the money needed to develop a clean technology business is consistently highlighted as a challenge for SMEs in the clean technology industry.

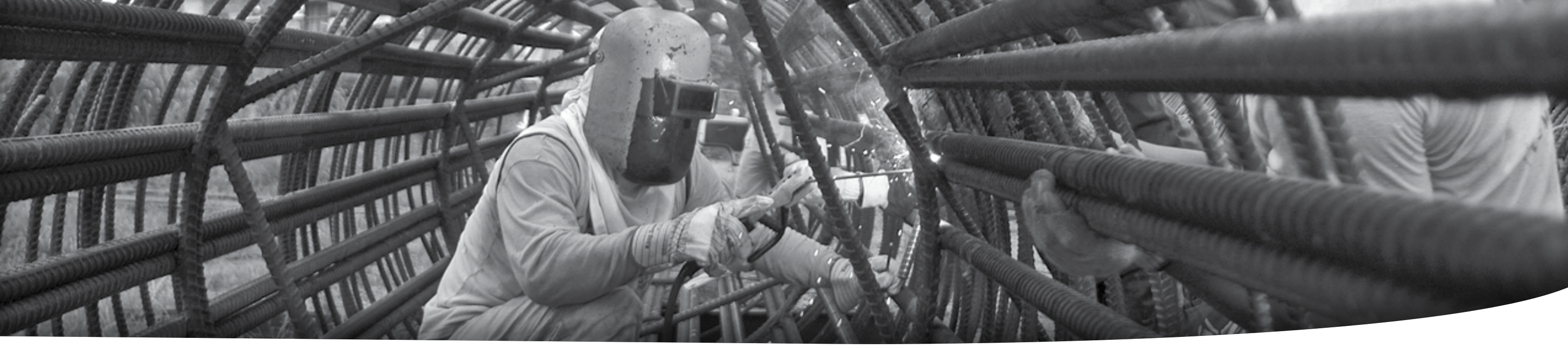


Photo: Nonie Reyes / World Bank.

Indeed, venture investment across all clean technology sectors in 2013 was 14 percent lower than in 2012, which itself was 24 percent lower than 2011 (Cleantech Group, 2014). While clean technology is growing as a sector, it is still developing, and raising VC has been a challenge recently. Many clean technology funds have not achieved the exits and returns they expected so capital for new ventures, particularly those at an early stage, is limited. However, venture investments account only for a small fraction of overall sector spending so its recent shrinkage does not undermine the sector's prospects, which are dominated by deployment numbers rather than VC spending. Moreover, this VC challenge is not unique to clean technology SMEs; many biotech companies also find it challenging to raise finance. For example, in 2012 the innovation capital raised by biotech companies with revenues below $500 million remained significantly below pre-economic crisis levels and raising capital was a top strategic priority for biotech firms (Ernst & Young, 2013).

The uncertainty of government regulation and policy is another key constraint on clean technology development, especially in developing countries where policies and regulations can be subject to frequent change. Many clean technology innovations depend at least initially on government regulation or policy to drive market growth, rather than consumer preference for a new product. Strong and consistent government regulation and clean technology policy can be key enablers for the clean technology industry and underpin early development and deployment. For example, the development and deployment of solar PV technology in Europe has been driven by subsidies, particularly feed-in tariffs in Germany and Italy. However, this reliance on government regulation and policy creates risks for investors and businesses that rely on long-term continuity since regulations and policies can change quickly. Some SMEs in other industries also face risks in this area (for instance, biotech companies that rely on government approvals for new drug developments), while firms in construction or ICT are less exposed to this risk since their sectors are more driven by consumer preferences and broader economic conditions.

SMEs play an instrumental role in furthering growth, innovation, and development, which coupled with a growing clean technology sector, can help build prosperity in the poorest countries.

Finally, technical and commercial expertise and experience is another limit for SME-driven clean technology development worldwide and is already an issue for the clean technology industry in many developed countries. There may be a lack of depth of experience technically or commercially in specific clean technology areas, hampering the development of vibrant clean technology SME communities in developing countries.

Despite these risks and barriers, clean technology markets exist and are growing, and their accessibility to SMEs represents a genuine opportunity.

Photo: John Hogg / World Bank.

BOX 3.1. Why focus on SMEs?

There are important niches for SMEs in established clean technology value chains. As discussed in Chapter 2, there are significant investment opportunities in developing countries, particularly prevalent in minor equipment manufacture, installation, civil works, retailing, and operations and maintenance activities. Knowledge of local markets, the need for specialization, and lower financial and technical barriers to entry makes these activities especially accessible to SMEs.

SMEs are well positioned to uncover and address opportunities in local clean technology markets. Local SMEs are deeply embedded in local markets, enabling them to identify appropriate business models, products, and services for these markets. Moreover, local SMEs have an advantage in base of the pyramid markets, which continue to be unattractive and impenetrable for many globally dominant firms.

SMEs play an important role in adapting existing technology for local conditions. SMEs are better disposed than large firms to the type of innovative entrepreneurship required to develop clean technology solutions that meet local needs. While large firms are constrained by their existing products, technologies, skills, and organization, firms that are small and young can more easily work outside dominant paradigms. SMEs have the flexibility to experiment and take risks, and are not discouraged by small markets of early technology adopters. This allows local SMEs to undertake the important work of adapting existing technologies for local conditions and customers.

Innovative SMEs face different barriers to growth. SMEs face different obstacles to growth than large firms. Lack of access to finance, lack of economies of scale, and lack of operational efficiency are just a few. Innovative SMEs face even more constraints due to greater asymmetries of information between sources of finance and SMEs, as well as higher rates of failure and longer-term returns on investments. Developing policy options that can specifically target clean technology SMEs is therefore critical to the successful development of clean technology industries in developing countries.

Value Chain Opportunities Most Easily Accessible to SMEs

The types of opportunity that exist for SMEs in developing countries differ by region but tend towards larger opportunities downstream in the value chain, in equipment component supply, installation and retrofit, customization, and operations and maintenance.

The major equipment segment of the value chain includes the technology element(s) that are specific to that particular technology. These include, among others, the wind turbine and tower, solar PV module, solar thermal collector; geothermal turbine; biofuel mills and fermentation tanks; water purification equipment; wastewater aeration basins and dewatering equipment; landfill construction; transit ways and buses; natural gas vehicle conversion kits.

The middle segment of the value chain, called balance of systems (BoS) or engineering, procurement, and construction (EPC), includes technology elements that are not specific to the particular technology and also project development costs. These include, among others, civil works; mounting structures; installation costs; common electronics and controls; general piping, wiring and fittings; planning and design; permitting; retailing; and sales and delivery.

The last segment of the value chain is operations and maintenance. O&M costs were calculated over the average expected lifetime of the technology and discounted to present values so that they could be sensibly compared to the first two segments of the value chain. Costs for O&M include, among others, routine maintenance and inspection; parts replacement; vegetation clearing; ongoing labor costs; vehicle operations; reservoir management; landfill leachate collection and treatment; warranty enforcement; and insurance.

Table 3.1 summarizes the value chain segments and Appendix B shows more detailed value chain breakdowns.

Growth opportunities also exist for SMEs that are already active and may have particularly relevant capabilities to leverage in adjacent markets. For many of these existing SMEs, the clean technology industry provides new opportunities for growth. For example, an electrician can begin installing solar

TABLE 3.1. Activities in the value chain for the 15 technology areas

Technology	Major equipment	EPC/BoS	O&M
Onshore wind	**57% (of the value)** Turbine	**22%** Civil works 44% Balance of system 31% Other costs 25%	**21%** Insurance Routine component and equipment maintenance Replacement parts & materials
Solar thermal	**45%** Solar collector	**37%** Civil works Balance of system Other costs	**19%** Routine inspection Maintenance of absorption and adsorption chillers
Solar PV	**54%** (>1 MW) **45%** (<1MW) PV module	**36%** (>1 MW) **46%** (<1MW) Civil works 57% Balance of system 29% Other costs 14%	**10%** (>1 MW) **9%** (<1MW) Routine inspection Preventative maintenance Corrective maintenance
Solar CSP	**36%** Solar field 80% Thermal storage system 20%	**55%** Civil works 35% Balance of system 30% Other costs 35%	**9%** Routine inspection Preventative maintenance Corrective maintenance
Small hydro	**23%** Electro-mechanical equipment	**57%** Civil works 65% Balance of system 25% Other costs 10%	**20%** Fixed costs Variable costs
Geothermal	**32%** Power plant	**45%** Civil works 40% Balance of system 30% Other costs 30%	**23%** Fixed costs Variable costs
Bioenergy	**42%** Feedstock conversion system 80% Prime mover 20%	**27%** Civil works 30% Balance of system 50% Other costs 20%	**32%** Fixed costs Variable costs
Biofuels	**46%** Major equipment	**27%** Civil works Balance of system Other costs	**27%** Fixed costs Variable costs
Water	**68%** Purification Distribution and storage Watershed management	**27%** Purification Distribution and storage Watershed management	**5%** Purification Distribution and storage Watershed management
Wastewater	**40%** Collection Treatment Final disposal	**50%** Collection Treatment Final disposal	**10%** Collection Treatment Final disposal
Municipal solid waste	**18%** Collection & recovery Sorting Treatment Final disposal	**23%** Collection & recovery Sorting Treatment Final disposal	**59%** Collection & recovery Sorting Treatment Final disposal
Natural gas vehicles	**95%** Natural gas conversion kit	**5&** Labor	**0%** n/a
Electric vehicles	**100%** Entire electric vehicle	**0%** n/a	**0%** n/a
Electric bikes	**81%** e-bike	**18%** Battery replacement	**1%** Equipment maintenance Labor
Bus rapid transit	**15%** Buses	**35%** Bus system	**50%** Buses Bus system

Source: Authors' analysis.

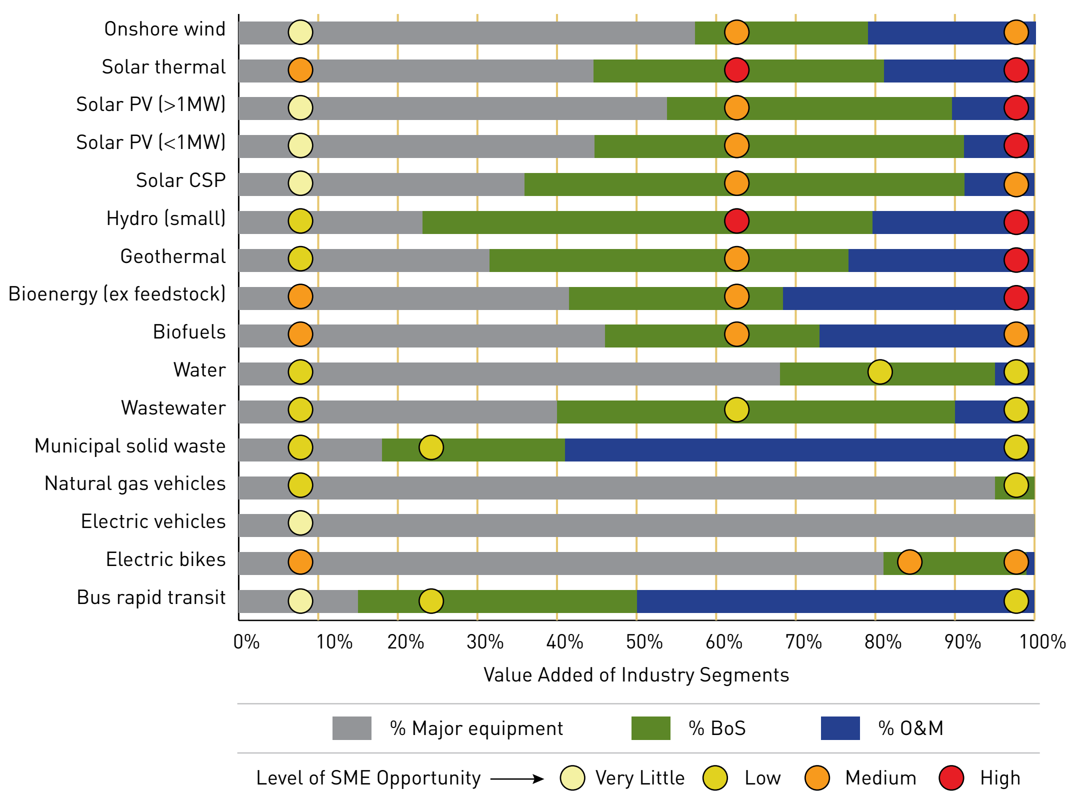
PV panels and a heating engineer who previously fit boilers can expand his business to install heat pumps.

A closer look at how the investment breaks down across the value chain sheds light on where the most promising opportunities might be (see Figure 3.1). For most of the renewables a significant portion of the investment is in major equipment, which is likely to offer less opportunity for SMEs. Downstream in the value chain, SMEs are likely able to capture over 50 percent of the market in a number of sectors. While opportunities also exist in highly specialized and technically sophisticated major equipment, customers tend to favor larger companies with significant access to capital in highly industrialized and vertically integrated markets. In general, the major equipment component segment of the value chain favors the more developed countries, with the exception of economies like China that have established and sophisticated manufacturing sectors.

Conclusion

The size and growth prospects of the clean technology sector present a large business opportunity for SMEs. However, not all technology sectors or value chain segments are equally accessible to SMEs. Policy makers should consider these variances when designing programs to support local SME participation in green industries. The next three chapters examine how policy has been designed in particular country contexts to capture such value and explores the results of those policy efforts.

FIGURE 3.1. SME opportunities in the value chain



Source: Authors' analysis.

Photo: John Hoggs / World Bank

Chapter 4

Case Study: Solar Energy in India

Main Points

- This case study takes a deep dive into the solar industry in India to illustrate the SME opportunity more clearly across the value chain segments and presents findings from a survey with 50 clean technology SMEs in India.
- Solar is particularly interesting in India because of the Indian Government's ambitious plans and targets for solar energy at small and large scales (as embodied in the Jawaharlal Nehru National Solar Mission). India is by far the world's most advanced market for small-scale concentrated solar power (CSP) for industrial heat, with supply dominated by local Innovative Indian technology suppliers.
- The SME opportunity in on-grid solar PV and CSP technologies over the next decade in India is roughly $41 billion, including lifetime O&M.
- The bulk of that opportunity is in the latter segments of the value chain: planning, installation, Balance of Systems, and O&M. Innovation opportunities also exist around customization of small systems for PV and accelerating the time between commissioning and operational readiness for CSP.
- According to the survey, Indian clean technology SMEs are working across value chain segments and innovation activities. However, they point out several barriers and suggest targeted policy support areas. Addressing these could provide opportunities for additional industry growth and SME participation.

BOX 4.1. Setting the scene: SMEs in India

After earning an engineering and management degree from the University of Pennsylvania, Siddharth Malik began working in the energy finance sector in the United States. But he was soon drawn back to India, where he could put his entrepreneurial character to work in the country's burgeoning clean technology sector. An ambitious innovator in his late twenties, Siddharth founded Megawatt Solutions, a renewable energy company specializing in concentrated solar thermal power. Three years later, he led the company through innovative pilots and demonstrations, and is now at the helm of India's largest solar industrial heating project, displacing diesel fuel and making up for a shortfall in biomass currently used by the pharmaceutical packaging industry in the state of Gujarat.

Siddharth personifies the buoyant and dynamic atmosphere that is permeating India's diverse clean technology market. With its large economy, surging demand for energy, active policy environment, and a commitment to slow the growth of greenhouse gas (GHG) emissions, Indian SMEs are capitalizing on the opportunities in the sector. While the survey shows that significant barriers persist, entrepreneurs like Siddarth are finding ways of overcoming them.

Photo: Ray Witlin / World Bank.

Solar Energy Market and Policies

India's energy demand is forecast to increase by about 40 percent over the next decade, from 630 Mtoe to over 880 Mtoe (U.S. EIA, 2013a). Meeting that demand will require enormous investment in new energy sources and electricity generating capacity. As a part of its effort to diversify its energy mix, India plans to install 22 GW of solar capacity by 2022, and over 40 GW of new wind power (Ministry of New and Renewable Energy-India, 2012a; GWEC, 2013; GWEC, 2012).

Of all renewable energy technologies, solar is one of the best suited for use in rural areas to help meet basic energy needs (Malaysian Commonwealth Studies Centre, 2012). Both decentralized, off-grid systems and larger scale, grid connected solar power are highly relevant to India. India has one of the world's highest solar intensities, with an annual solar energy yield of 1,700 to 1,900 kilowatt hours per kilowatt peak (kWh/kWp) of installed capacity (Germany has an average of 900 kWh/kWp) (McKinsey, 2008, 2013b). India also has about 300 clear, sunny days per year (Muneer, Muhammad, and Munawwar, 2005).

Since India's resource base is suitable for the whole breadth of solar technologies, grid connected and off-grid solar photovoltaic as well as CSP[16] and solar thermal technologies are all discussed in this case study. They are all relevant to the Indian context and represent different market niches and commercial opportunities for SMEs.

Of all renewable energy technologies, solar is one of the best suited for use in rural areas to help meet basic energy needs.

The Jawaharlal Nehru National Solar Mission, part of India's National Action Plan on Climate Change (NAPCC), was launched in January 2010 to promote the development and use of solar power. It is the foundation for policies and programs that are accelerating deployment of both grid-connected and off-grid solar power, encouraging deployment of solar thermal collectors, and improving conditions for solar manufacturing capability in India, particularly in the local supply chain (Ministry of New and Renewable Resource-India, n.d. (a)).

The government has also established institutions and centers to facilitate solar development. The Solar Energy Centre, accredited testing facilities, workforce training programs, and research and technology validation projects. The Solar Energy Corporation of India, a not-for-profit organization, promotes R&D, selects sites for solar power stations, sets up transmission facilities, and owns, operates, and manages projects (Solar Energy Corporation of India, 2014). The Ministry of New and Renewable Energy (MNRE) organized the Solar Mission into three phases and set targets for each phase (Ministry of New and Renewable Energy-India, 2012). As of June 2013, greater than 85 percent of the 652 MW Phase I grid connected Solar PV targets have been deployed. Some delays have been experienced for CSP (projects have been selected, but no new CSP has actually been brought online). State policy is also driving the solar market, especially where the natural solar resource is particularly strong (that is, Gujarat, Rajasthan, and Karnataka).

16 It is also important to clarify India's solar nomenclature. National documents refer to CSP as "solar thermal," and refer to what is traditionally called solar thermal as "solar collectors." In this case study, the term "CSP" refers to technology that uses reflectors to concentrate solar energy for use as electricity or heat, and "solar thermal" refers to flat plate or evacuated tube solar collectors that are used to generate heat, usually hot water, but not electricity.

BOX 4.2. India's Feed-in Tariff Experience

Feed-in tariff (FIT) schemes have been successful at accelerating renewable energy deployment in Germany and Spain, but have also sometimes burdened consumers with fixed long-term contracts that deliver windfall profits to developers who take advantage of falling technology costs and slow-to-adjust government support. In India, the Central Electricity Regulatory Commission (CERT) analyzed the market and set a benchmark FIT, a maximum rate that can be offered to developers. The Indian government also requested project proposals from developers in a 'reverse auction', where developers submit their plans and any discount they can offer from the FIT. In practice, 44 percent of the developers offered hundreds of megawatts at significantly lower cost. As a result, the government awarded 140MW of solar PV capacity at an average of 32 percent below the CERT benchmark tariff, and 350MW of PV capacity at an average of 43 percent below the benchmark (Phase I). For CSP, the average tariff was 25 percent lower than the benchmark. While this is advantageous for consumers and efficiently allocates scarce government resources, it may favor large power producers who can leverage economies of scale and established supply chains to reduce costs, and use their financial strength to cushion against cost overruns or overestimated power production.

India also has many different incentives designed to encourage the deployment of different sizes and types of solar technology, including feed-in tariffs, capital cost subsidies, exemptions from electricity tax, tax concessions, and exemption from electricity demand cuts to those who produce rooftop solar power. The feed-in tariff (see and some capital subsidies are administered nationally, while state governments manage other policies.

The SME Opportunity in the Indian Solar Market

On-grid solar PV and CSP technologies are among the largest clean technology SME opportunities identified in India. Taken together, the SME opportunity for solar development over the next decade is estimated at about $41 billion, including lifetime O&M (see Table 4.1). The bulk of that opportunity is in the latter segments of the value chain: planning, installation, and Balance of Systems, and O&M. Planning, installation and Balance of Systems activities have smaller upfront capital costs and require less technical sophistication. O&M activities will grow cumulatively as technologies are deployed, creating business opportunities that are suitable for new entrants or existing SMEs looking to grow their service offerings.

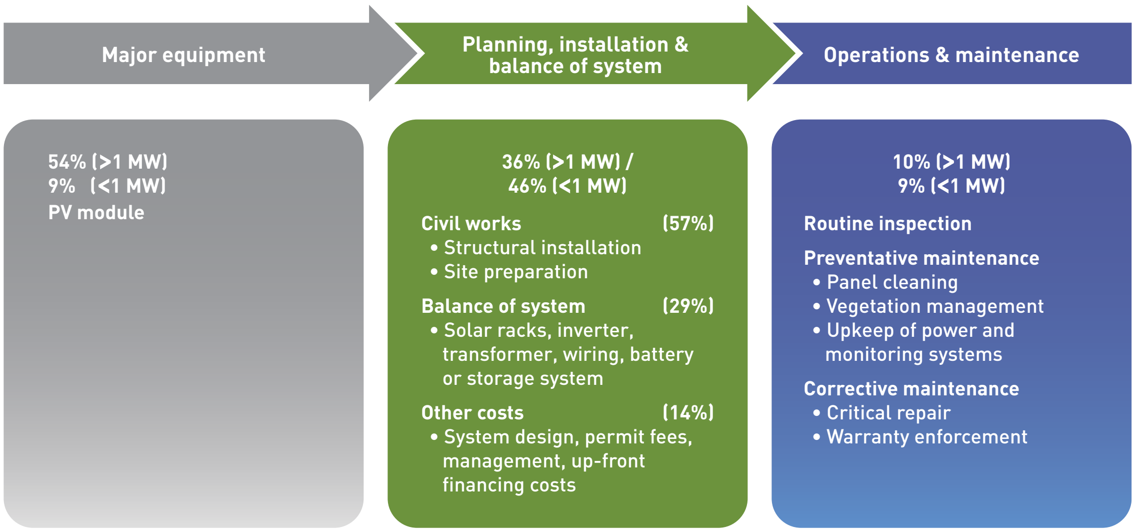
The solar thermal sector is expected to be a smaller market compared to solar PV and CSP, and the opportunities for SMEs are spread more evenly across the value chain. Considering the size of the market opportunities, this chapter explores the solar PV and CSP market in depth.

TABLE 4.1. SME Solar opportunity by value chain segment in India over the next 10 years ($ billion)

Solar subsector	Major equipment	Planning, installation & BoS	O&M	Total
Solar PV	0.8	15.0	5.5	21.3
CSP	0.5	13.9	2.2	16.6
Solar thermal	1.3	1.7	0.9	3.9
Total	**2.6**	**30.6**	**8.6**	**41.8**

Source: Authors' analysis.

FIGURE 4.1. Solar PV value chain



Source: Authors' analysis.

The Solar PV Market

The solar PV market opportunity in India potentially exceeds $60 billion over the next decade, with over $21 billion accessible to SMEs.[17] The solar PV value chain can be broken into three major stages, as shown above. SME prospects are strong in the latter two stages of the value chain, which together comprise 45 to 55 percent of the total value of solar PV systems and where about 95 percent of SME value lies.

Opportunities for Indian SMEs for each of the value chain segments of the solar PV market are discussed below:

- Major equipment:
  - Manufacturing of cells and modules is thought to be neither an area of particular strength for SMEs nor an area where India is competitive internationally. Government rules are trying to change that, but this may have unintended effects since domestic content rules for solar PV modules are encouraging developers to install imported thin film solar instead, which is not subject to domestic content rules.
  - Local crystalline PV module manufacturers were supported by the Indian government's Domestic Content Requirement (DCR) for Phase I of its PV deployment schedule. In Phase I Batch I, projects using crystalline modules needed to ensure they were made in India (though the firm could be foreign owned), and in Batch II, crystalline PV cells and modules both had to be domestically produced. Thin film solar PV was exempt from the DCR. The DCR is being challenged by the United States through the World Trade Organization, but the requirement has nevertheless been extended to Phase II, though reduced to only 50 percent of the 750 MW target (PV Magazine, 2013). Thin film is still exempt (Ministry of New and Renewable Energy-India, 2013).
  - While these rules are attempting to shape the domestic manufacturing market in India's favor, the reverse may actually be happening. Indian crystalline modules can be more expensive and of lower quality than foreign ones, and experts believe that the absence of a DCR for thin film PV may be driving India's peculiar appetite for the technology: about 42 percent of modules in India are thin film, compared with only about 10 percent of the global market share (Sahoo and Shrimaliy, 2013; PV Tech, 2013; Four Peaks Technologies, 2011). And while the Indian crystalline PV supply chain has decent capacity in cells and modules, it is struggling to compete with Chinese equipment

17 To determine the share of each segment of the value chain that could be accessed by SMEs, an assumed global average was applied across all regions.

manufacturers, as the capacity map clearly shows (see Figure 4.4).

- Planning, installation, and balance of system:
  - The balance of system components like the solar rack, inverters, transformers, wiring, and battery storage systems are widely produced by domestic SMEs, like Kripa Power Systems, which sells inverters, or Tara Solar, which sells mounting racks (The Solar India, 2013; Kripa Power Systems, 2013; Tara Solar, 2013). Many other elements are inherently local, such as structural installation and site preparation. System design, permitting, and project management also require the kind of bespoke engineering consultancy and planning services that are better suited to local firms.
  - Customization of systems to suit smaller, off-grid loads are rapidly gaining popularity, especially since the cost of PV modules has fallen so dramatically. Small PV retailers are outfitting shops and small businesses with systems to offset the cost of purchased electricity and to keep merchandise cold and other systems operational in the event of power cuts.
- O&M: These activities are crucial to maintaining high performance and successfully operating solar PV equipment. O&M activities last for the lifetime of the projects and grow as the cumulative stock of installed PV equipment expands. For these reasons, O&M activities are likely to be an increasingly lucrative and fast-growing market.

The CSP Market

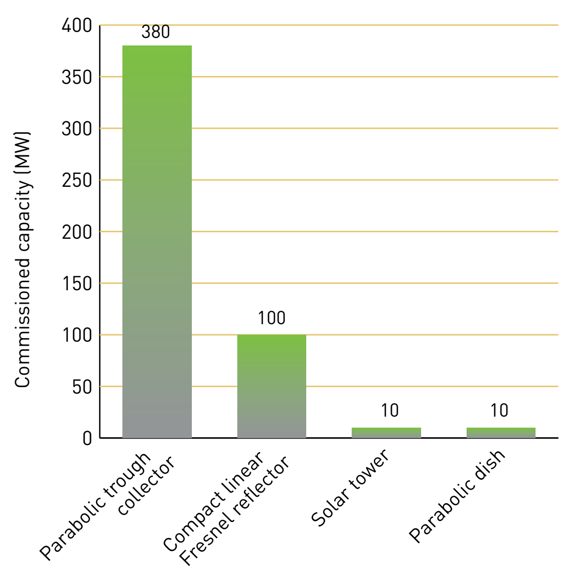
India's CSP market is projected to be worth up to $45 billion over the next decade, with about $16.5 billion accessible to SMEs for grid-connected CSP alone. CSP technology has two major types of application: CSP for electricity, where water is turned into steam and used to drive turbines; and CSP for heat, where heat or steam is used for medium-energy intense industrial processes like cooking, laundries, bakeries or dairy pasteurization.

Grid-connected CSP has several advantages over PV. Thermal energy storage systems, with which CSP can be equipped, help buffer against transient cloud cover and enable the technology to generate electricity after sunset. They also may allow operators to distribute electricity at peak times and enable hybrid operation capability with other fuel types to meet base-load energy demands. Some CSP technologies have better conversion efficiencies than PV, and, depending on their level of sophistication, can be made at low cost. The drawbacks of CSP technology include the need for direct sunlight (PV works even under cloudy conditions), the relative immaturity of the technology, the consequent difficulty in securing low-cost finance, and the relatively long lead-times required from concept to operation.

As previously mentioned, the first call for 500 MW of grid connected CSP was fully subscribed under the National Solar Mission. The distribution of CSP technology types that were selected under Phase I of the National Solar Mission is shown in Figure 4.2. The first 50 MW parabolic trough installation came online in June 2013, but most companies have been delayed bringing their systems online (Godawari Green Energy, 2013).

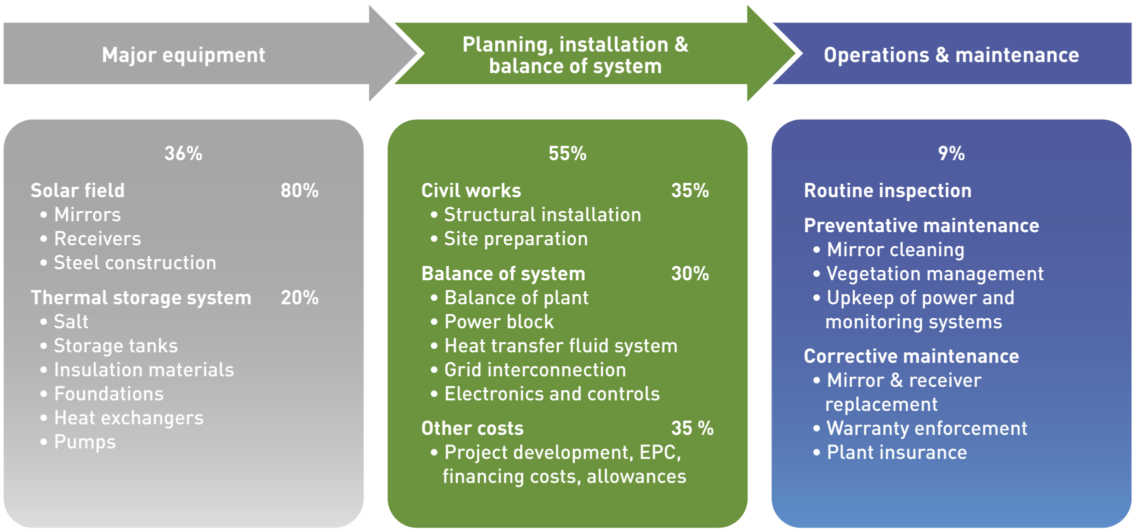
Like PV, the SME opportunities for this technology lie mostly in the latter two stages of the value chain, which together comprise up to 65 percent of the total value of the CSP market and about 95 percent of SME value lies.

FIGURE 4.2. Technology choice for grid connected CSP



Source: Ministry of New and Renewable Energy-India, 2012b.

Figure 4.3. CSP value chain



The opportunities for Indian SMEs for each of the value chain segment are discussed below:

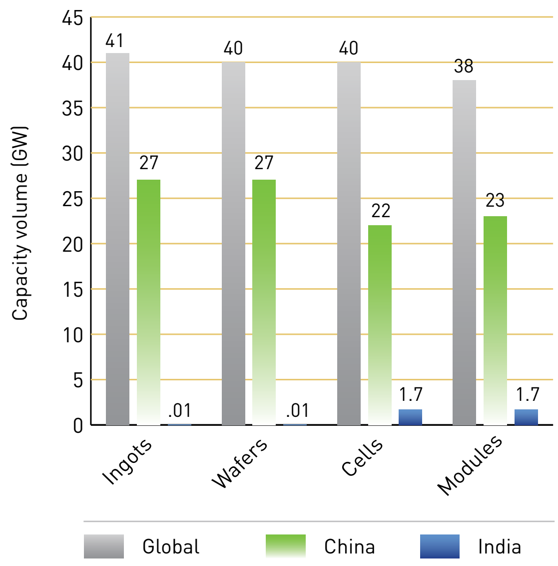
- Major equipment:
  - Seven companies were awarded CSP contracts under the National Solar Mission, and one (Aurum Renewable Energy Pvt Ltd) was an SME. It was awarded 20 MW of CSP capacity, or 4 percent of the total (Aurum Ventures, 2013). SMEs are not completely shut out of this segment of the grid connected CSP value chain will have some opportunities.
  - For off-grid CSP, especially CSP for heat, the opportunities for SMEs in the major equipment segment are significantly better. For example, the Scheffler dish is a parabolic dish design that can easily be manufactured locally in developing countries, and was intentionally designed to be manufactured anywhere. The design specifications are freely available online and systems can be assembled using basic engineering skills and easily available materials. India is also by far the global market leader in small-scale off-grid CSP, which may create export opportunities as other markets catch up. Another solar concentrator used for thermal applications is called ARUN and was designed by an SME called Clique Solar. There are 15 ARUN dishes in operation, all in India, which are used for process heat in the dairy and hotel industries (Clique Solar, 2013).
- Planning, installation, and balance of system:

  About 50 percent of the latter segments of the value chain are thought to be accessible by SMEs. Many of these components are less technically sophisticated and would require less upfront capital investment to develop and produce. Many of the services are inherently local, such as engineering consultancy, permitting, site preparation, and structural installation.
- These activities are considered to be quite accessible to SMEs, especially new startups, since several of the O&M activities require minimal initial inputs.

Innovation Opportunities in the Indian Solar Market

Analysis of India's innovation system questions whether it has the competitive enablers that China's system does. China's global market share for PV production grew from less than 2 percent in 2002 to 45 percent in 2010, while India's fell from 4 percent to 2 percent over that period. It is argued that China's institutional coordination, wide-ranging capital and resource subsidies, deep and responsive R&D support, and upstream and downstream corporate integration made Chinese PV extremely competitive. China also offered cheap financing, which reduced equity requirements and gave firms the freedom to operate with

FIGURE 4.4. Capacity map for crystalline PV (global, China, India)



Source: Sahoo and Shrimaliy, 2013.

lower returns, and had a DCR that covered all PV technologies rather than just crystalline.

India lacks the same degree of institutional integration, has an unreliable electricity supply, has an R&D agenda that is more driven by the public sector than the private sector, and has a DCR that covers only crystalline technology (Sahoo and Shrimaliy, 2013). For these reasons, the major equipment stage of the PV value chain is not likely to gain a significant competitive edge, and is considered to be an especially limited opportunity for SMEs. However, there are particularly strong technology-specific innovation opportunities for solar PV around customization of small systems, including roof-mounted ones and off-grid bespoke applications for small power requirements. From an R&D perspective, there is innovation potential for solar PV cells and modules to be calibrated to India's latitude rather than the irradiance spectra that are more common in European markets. For CSP, innovation is needed to accelerate the time between commissioning and operational readiness, since that has been a major stumbling point for the CSP commissioned under Phase I of the National Solar Mission. For solar thermal, innovation is needed to improve integration with other energy sources.

Innovative financing arrangements are needed to open up the market to potential customers with limited upfront capital. The Asian Development Bank is experimenting with pay-as-you-go schemes in partnership with Simpa Networks, an SME that is helping energy-poor households access solar energy using a solar home system and a low-cost prepaid meter connected to cloud-based software (ADB Knowledge Showcases, 2013). Accessing low-cost finance is also important for larger-scale projects, especially in the highly competitive cost environment that is encouraged by the reverse-auction approach to feed-in tariffs. Innovation is also needed to improve the degree of technical quality assurance, which would help build trust in a technology's claimed specifications so that developers and financiers can reduce technology risk and financing costs.

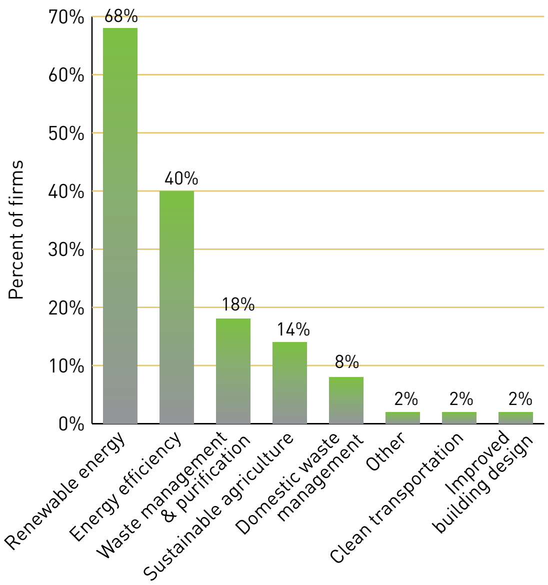
Indian Clean Technology Firm Survey Results

A survey of 50 clean technology firms in India suggests that a large majority of the firms are active in renewable energy, including solar; 68 percent of firms said they worked in renewable energy, 40 percent are in energy efficiency, and 18 percent worked in waste management and purification (note that firms could select more than one sector) (see Figure 4.5). These commercial activities largely reflect the areas of greatest opportunity that were identified through the market sizing study, and may reflect the fact that firms are choosing to get involved in sectors that are growing.

The survey also revealed that clean technology SMEs are already working in the value chain segments with the most opportunities for SMEs (see Figure 4.6). Most firms said they worked in several different parts of the value chain, with over 70 percent of firms working in design and/or O&M, and over 60 percent working in one or more of installation, manufacture and assembly, and/or R&D.

The surveyed firms were also international, and significantly more international than non-clean technology firms in India (World Bank, 2006). Nevertheless, 70 percent of firms said that more than three-quarters of their sales came from domestic customers. Forty-six percent of firms had customers overseas, 43 percent of those firms had customers in Africa and non-China Asia-Pacific,

Figure 4.5. Sectors in which Indian clean technology SMEs are involved



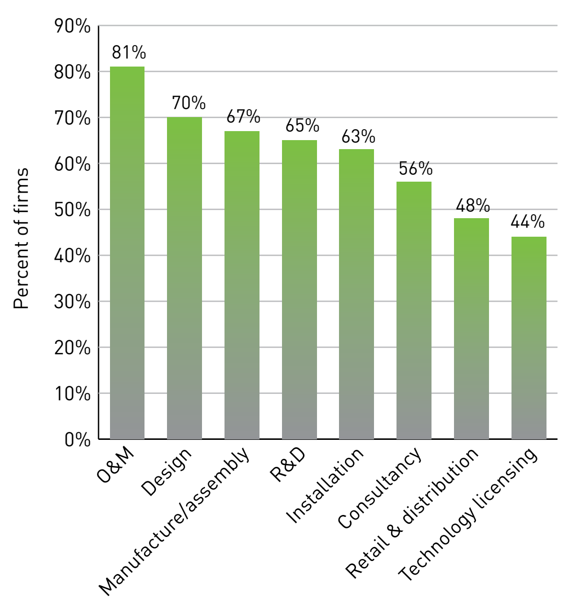
Source: Survey of clean technology firms in India undertaken in July and August 2013.

Photo: Ray Witlin / World Bank.

and more than 30 percent had customers in each of Europe, North America, and the Middle East. Sixty-six percent had suppliers based in a foreign country, hailing mostly from China and Europe (61 percent each) but also from North America (39 percent) and other parts of East Asia (30 percent). A further 30 percent of firms identified international expansion as a priority.

Overall, the firms expressed a high level of optimism about the current and future Indian clean technology market: 88 percent of the firms indicated that they were either very (62 percent) or fairly (26 percent) confident about their business environment in India. The surveyed firms' historical and projected growth also showed promising signs: 94 percent experienced sales growth in 2013 and nearly 70 percent of the firms purchased fixed assets in 2013, reflecting their willingness to invest and suggesting their confidence and optimism about the market. Further evidence of optimism and growth expectations can be seen in the fact that 96 percent of the firms expected the number of employees focused on clean technology to increase over the next three years (with 53 percent expecting a large increase).

Figure 4.6. Activities in which Indian clean technology firms are involved



Source: Survey of clean technology firms in India undertaken in July and August 2013.

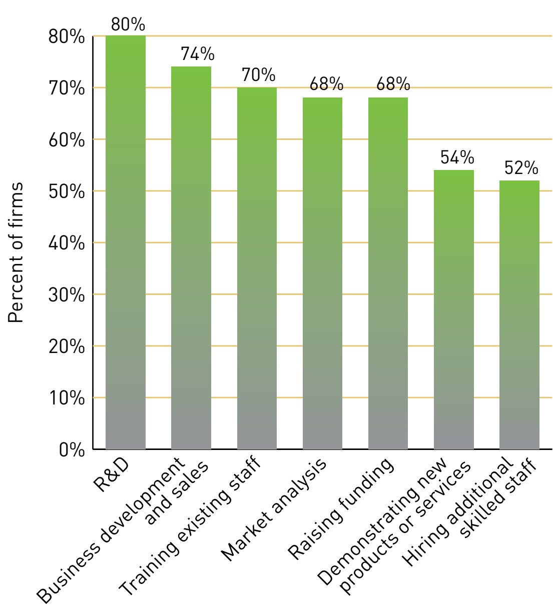
Indian clean technology firms are avid innovators. Over the past two years, about 70 percent of surveyed firms introduced new or significantly improved clean technology products or services, methods of manufacturing their clean technology products, and process-based activities to enhance clean technology product delivery (see Figure 4.7). Such innovation across such a broad spectrum of indicators suggests that firms are responding to the dynamic market conditions that are present in India.

As with any market, there are barriers to the rapid scale-up and deployment of solar technologies in India. The top two barriers identified by the clean technology firms surveyed in India for this report are shown in Figure 4.8.

The most commonly cited barrier by far was access to finance, which is particularly problematic considering that 84 percent of surveyed firms plan to raise funding in the next two years. This barrier was particularly acute for the surveyed clean technology firms compared to average Indian firms, who considered access to finance to be the fifth biggest obstacle to their business. To overcome this barrier, efforts could be made to educate finance providers about the real risks posed by investments in solar, including the strength of contractual guarantees on product performance and the longevity and robustness of the feed-in tariff. Likewise, developers could benefit from support in writing detailed and realistic business cases that meet the standards of lenders.

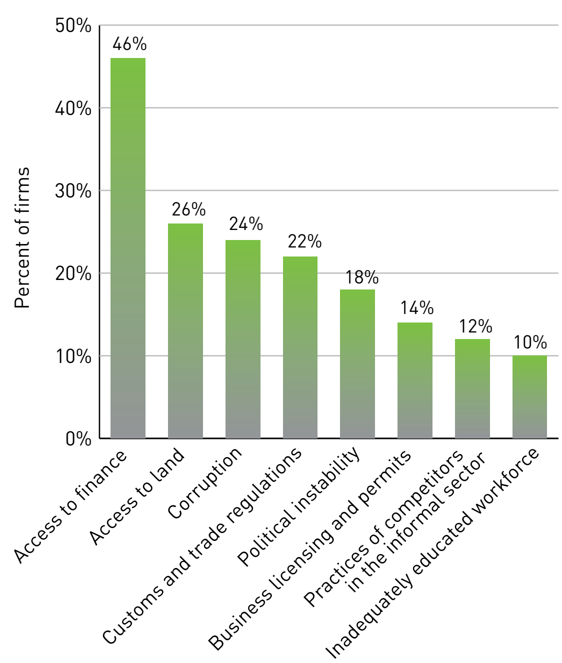
Access to land, corruption, and customs and trade regulations were also significant barriers for clean technology firms. A lot of clean technologies require access to land, especially large-scale solar, which may underlie this concern, but a focus on rooftop solar PV (which does not require additional land) or smaller, more customized PV applications could mitigate this issue. When asked what the government could do to help overcome these barriers and foster growth in clean technology, surveyed firms indicated a range of potential areas where help would be welcomed, as shown in Figure 4.9. These results show that there is a wide range of different government interventions that would be welcomed by clean technology firms.

Figure 4.7. Innovation activities undertaken by clean technology SMEs in India



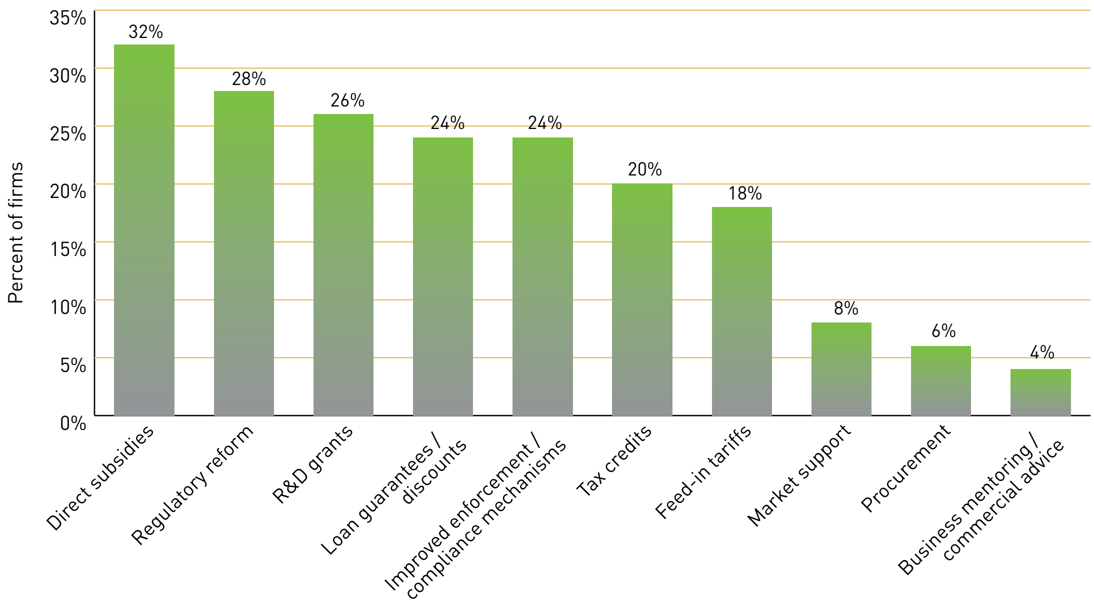
Source: Survey of clean technology firms in India undertaken in July and August 2013.

Figure 4.8. Most common barriers faced by clean technology SMEs in India



Source: Survey of clean technology firms in India undertaken in July and August 2013.

Figure 4.9. Areas for government support identified by clean technology SMEs in India



Source: Survey of clean technology firms in India undertaken in July and August 2013.

Conclusion

The clean technology market is set to grow in India. Over the next decade, economic growth will be bolstered by India's large population, peaking labor force participation rate, increasingly educated and skilled workforce, and the emergence of a wealthier and more urban middle class.

Significant investment in solar power, which is especially well suited to India's climate and geography, is being driven by the National Solar Mission, the feed-in tariff and falling technology costs. The SME opportunity in on-grid solar PV and CSP technologies over the next decade is about $41 billion, including lifetime O&M. The bulk of that opportunity is in the latter segments of the value chain: planning, installation, and balance of systems, and O&M. Innovation opportunities exist around customization of small systems for PV and accelerating the time between commissioning and operational readiness for CSP.

According to surveys of clean technology SMEs in India, firms are optimistic about the market and are active in innovative activities. However, they highlight several barriers to entrepreneurship such as access to finance and land. Removal of these barriers and providing targeted policy support (for instance, loan guarantees or subsidies, marketing and sales support, and improved access to technical R&D facilities) could provide opportunities for additional industry growth and SME participation.

Chapter 5

Case Study: Bioenergy in Kenya

Main Points

- This case study takes a close look at the bioenergy industry in Kenya to illustrate the barriers and opportunities in the various subsectors, including examples of Kenyan SMEs. It also presents findings from a survey with 50 clean technology SMEs in Kenya.
- Bioenergy already plays a significant role in Kenya's energy mix. It is entrenched in Kenyan domestic and working life and as such presents an excellent opportunity for local SMEs to grow the sector and make it more sustainable.
- The SME opportunity in bioenergy—efficient biomass, biogas, crop-based biofuels, and cogeneration or combined heat and power—is abundant but specific to certain technologies or geographical locations. Investment of $2.4 billion is expected in the East African bioenergy sector, with almost $1.4 billion accessible to SMEs, and Kenyan SMEs may benefit from these opportunities.
- Kenyan SMEs face a number of barriers including incoherent bioenergy policies, high cost of investment/access to finance, lack of business skills, and so on. Despite the challenging environment, the survey of clean technology SMEs in Kenya suggests that firms are optimistic about the clean technology market and have strong growth ambitions. Some Kenyan clean technology SMEs are highly innovative and are developing pioneering financing models and new products and services.
- Removing key barriers and providing targeted policy and business support could provide opportunities for additional industry growth and SME participation.

Kenya's Bioenergy Market and Policies

Bioenergy is a renewable energy made from biomass, which is organic material derived from plant or animal matter. Three main sources of biomass are used to produce modern bioenergy in Kenya: naturally occurring biomass (for instance, from trees or manure); industrial biomass waste from agro-industries; and crops grown commercially with the sole purpose of biofuel production. This case study considers all three sources but excludes charcoal. Biomass can be used to supply heat, power, gas, and transport fuel.

Biomass currently accounts for 70 percent of total energy demand (90 percent of rural household energy needs—33 percent in the form of charcoal and the rest, firewood). There is also over 1.8 million metric tons of estimated bagasse production with a potential to generate 120 MW of electricity. Bioenergy has great potential to continue to play a significant role in Kenya's energy mix. It is already entrenched in Kenyan domestic and working life so it would be easier to build upon existing industries than develop new ones. Furthermore, bioenergy is particularly suited to Kenya's level of development: it can provide off-grid power solutions to remote areas; much of the infrastructure involved is low-tech and/or available

Photo: Curt Carnemark / World Bank.

BIOENERGY ... CAN PROVIDE OFF-GRID POWER SOLUTIONS TO REMOTE AREAS; MUCH OF THE INFRASTRUCTURE INVOLVED IS LOW-TECH AND/OR AVAILABLE ON SMALL SCALES...

on small scales; and it is fed by a resource that Kenyans are able to produce on a range of scales.

If poorly managed, however, a focus on scaling up bioenergy could lead to other environmental problems. In the past, exploitation of forests for biomass has led to large-scale deforestation (National Climate Change Action Plan 2013-2017- Kenya, 2013). Additionally, charcoal, which provides 82 percent of urban fuel consumption and which is the largest rural employment sector in Kenya after agriculture (Hunt, 2013), is a source of dangerous indoor air pollution (Kenya's Energy Regulatory Commission, 2004). It is also inefficient, typically 60-80 percent of the energy in the wood is lost and charcoal stoves are particularly wasteful, operating at efficiency rates as low as 3 percent. The environmental issues associated with some forms of bioenergy make it important that any future development is managed sustainably.

The overall government approach to bioenergy is inconsistent and could be clarified further to provide market certainty. The National Climate Change Action Plan (NCCAP) of 2012, an action plan based on the 2010 National Climate Change Response Strategy (NCCRS),[18] includes developing industrial-scale cogeneration using biogas from agricultural residues and introducing a 10 percent biodiesel fuel blend into liquid transport fuels.

18 See "National Climate Change Action Plan 2013 -2017: Executive Summary." *Republic of Kenya*. 2012. http://cdkn.org/wp-content/uploads/2012/12/Kenya-Climate-Change-Action-Plan_Executive-Summary.pdf

BOX 5.1. Setting the scene: SMEs in Kenya

A socioeconomist by training, Samson Gichia started his career as a research assistant at the International Centre of Insect Physiology and Ecology. Testing his entrepreneurial instincts, in 2007 he started a family-run maize milling business, raising the startup capital from his personal savings. In 2010, Samson's ambitions grew as he sought to provide a solution to one of Kenya's most pressing problems—rural energy provision. In response, he founded Cobitech Limited, a bioenergy company specializing in the construction of fixed dome biogas systems. These systems are aimed at both domestic household clients with access to livestock waste to use as feedstock and organizations like Naivasha Water and Sewerage Company, where human biowaste can be utilized as feedstock for biogas generation. Cobitech currently has ambitious plans to build a 2 MW biogas plant in Kiambu County with the aim of generating renewable energy in rural areas across the country for onward sale to government.

Samson is in many ways typical of Kenyan clean technology entrepreneurs—driven to find solutions to local problems, willing to put his own resources behind his ambitions, and eager to take advantage of startup support mechanisms available in the region. Cobitech has already sought out support from several organizations, winning prizes and getting assistance ranging from mentorship support to capital finance.

With Kenya's position as a regional hub, the process of East African Community (EAC) integration well underway, and a significant number of innovation support facilities dotting the country, Kenyan entrepreneurs are well placed to lead on clean technology innovation for the region. Although as shown later in this chapter, significant barriers remain.

It also has plans for maintaining and increasing forest cover (that is, a minimum of 10 percent of land) and promoting improved cooking stoves and LPG cooking stoves. A Biofuel Policy, drafted in 2010 has yet to pass through Parliament. The absence of a formally acknowledged policy framework presents uncertainty as to what support or restrictions may be offered or imposed in the future. A further indication that the government may be reluctant to support bioenergy is that its potential negative impacts are presented without any suggestions as to how they could be resolved. These impacts include competition for agricultural land, resulting in increased food prices, and extensive rural biomass consumption, causing deforestation and widespread biomass scarcity.

The Kenyan government introduced a feed-in tariff (FIT) to allow renewable electricity producers, including from biogas, to sell electricity to Kenya Power and Lighting Company Limited at a fixed price for a given length of time (Energy, Environment, and Development Network for Africa, 2009). First introduced in 2008, it has been reviewed twice, in 2010 and 2012, because the FIT price was insufficient to attract significant investment. The government also developed a strategic plan for biodiesel (2008-2012) to be used both in transport (10 percent blend by 2020) and electricity generation. The government hopes that growing biofuel feedstocks on marginal land will not impact food security and expects the biodiesel industry to sustain itself without state subsidy after a short term of government monetary support and plans to tax biodiesel production in the long run.

The SME Opportunity in the Kenyan Bioenergy Market

The increased (and more sustainable) use of biomass, biogas, crop-based biofuels, and cogeneration presents a range of opportunities for SMEs. While bioenergy (including biofuels) is forecast to reach a relatively small market size compared to small hydro, geothermal, and PV in East Africa, this is partly because of the relatively low capital investment required to enter the market, which makes it a particularly appealing market to SMEs and entrepreneurs. The Kenya Climate Innovation Center[19] for example, has 33 of its 79 clients active in the bioenergy and biofuels sector. Opportunities related to bioenergy are discussed below.

More efficient use of biomass

Products like improved cooking stoves and biomass boilers have significant benefits for end users: they reduce fuel costs for the purchase of wood or charcoal; improve indoor air quality thereby reducing associated health problems; and reduce the time spent by individuals in finding fuel. Key barriers include a lack of financial investment and lack of awareness among end users.

Biogas

Biogas digesters convert water and organic material into a gas, which can be used as a fuel, often replacing LPG. This technology is available on different scales—domestic, community/institutional, and commercial.

Domestic biogas digesters are low-technology constructions involving concrete or plastic tanks. There has been some take-up of biogas digesters since the 1950s, but certain barriers restrict wide-scale installation. The quantity of organic material required to power the digester (at least two cows which must be standing) is unsuitable for pastoralists and some farmers (Hunt, 2013; Resources, Conservation and Recycling, 2010). It also uses about four buckets of water per day, making it inappropriate in some water-scarce areas of the country. Many biogas digesters have fallen into disrepair because of poor maintenance—the Africa Biogas Partnership Program (ABPP) reports that only around half of all biodigesters installed were still operational in 2008. Demand is further limited by the large upfront installation cost of KES 100,000-150,000 (about $1,100-1,700). However, large donor funded programs like the Kenya National Domestic Biogas Program (KENDBIP) are working to reduce the investment cost barrier of domestic biogas installations by providing a subsidy. This market will most likely be driven by donors, government, and NGOs in the short and medium term.

19 The Kenya Climate Innovation Center is one of the business incubators supported by the World Bank/*info*Dev's Climate Technology Program. For more information, see www.infodev.org/climate

SMEs focused on adapting or making biogas digesters more suitable for domestic users, by providing a more tailored service (for instance, pay-as-you-go business models, including lifetime servicing which reduces the barrier of high up-front investment costs), could generate more demand for these products. An example of an SME applying business model innovation is presented in Box 5.2.

There is high potential for industrial-scale biogas in Kenya because many substrates from typical Kenyan agricultural production and industry can be used to produce biogas. Industrial-scale biogas technology is exploited in dairy, slaughterhouses, and farms. A number of donors have also undertaken feasibility studies for different industries to assess their potential and encourage investment. A study by GIZ found that municipal solid waste from Nairobi had the highest potential for a single input, followed by sisal waste, coffee production, and certain food processing (German Biomass Research Centre, 2010). Two SMEs operating in the industrial bioenergy sector are described briefly in Box 5.3.

BOX 5.2. Takamoto Biogas

Takamoto Biogas is one of the 52 SMEs currently registered with the Kenya Climate Innovation Center, which was established by *info*Dev's Climate Technology Program (Anjarwalla, 2013). Established in 2011 by a Brown University graduate, it employs a mix of eight Americans and Kenyans. Its target market is the domestic household, selling biogas appliances such as stoves, water heaters, and lamps and also providing installation of the digesters (Takamoto Biogas, 2013). It is currently rolling out its new innovative financing mechanism, the pay-as-you-go system, to address the high installation cost that acts as a barrier to many households. Under this system, customers pay a small upfront cost (about one-tenth of the normal price) and then pay per usage, utilizing smart meter and mobile phone technology (Anjarwalla, 2013). Fifty systems have so far been installed through a pilot project (Anjarwalla, 2013). Takamoto Biogas hopes this scheme will expand its market and improve access to biogas technology in rural areas.

takamotobiogas

BOX 5.3. Nairo-Bio Limited and Four for One Trading Services

In 2012 Evans Kamau Munira, a Swedish-Kenyan entrepreneur, won the European-African Entrepreneurship Award for his proposed biodiesel business venture. After substantial market research he had created a business model that involves turning used cooking oil into biodiesel. The company plans to source the equipment from Sweden and the oil from local waste producers and then to sell to transport firms and private fuel stations. It addresses the need in the market for a cheaper fuel source for transport as imported fossil fuels become unaffordable, accounting for a significant portion of total costs borne by companies. The plan also capitalizes on the zero-rated duty for imported clean technology processing equipment and the availability of waste cooking oil at low cost (it currently presents a disposal problem for many restaurants).

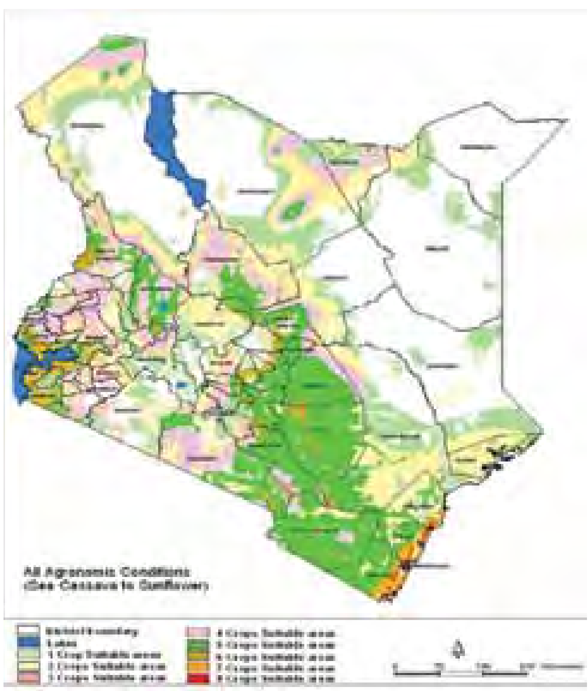
Four for One Trading Services is another SME supported by the Kenya Climate Innovation Center. In contrast to Takamoto Biogas, it operates in the industrial biogas market, targeting companies that produce large quantities of organic waste, such as the dairy and sugar sectors. It offers services in the design, construction, and operation of biogas plants and employs 88 skilled workers, besides expecting to employ at least six technicians at each industrial installation (Four for One Trading Services, 2013). In its targeted approach it has managed to exploit huge demand, with over 500 clients in four years. Four for One Trading Services integrates technological innovation into its business model. First, it claims to have a unique biogas digester system, the Ambita model, which produces almost twice as much biogas as conventional systems, and furthermore it is looking at novel feedstocks, such as investigating the potential for creating biogas from the hyacinth weed that is a pest for fishermen on Lake Victoria (Kenya Climate Innovation Center, 2013).

Crop-based biofuels

Crop-based biofuels have not had particularly good success in Kenya. Jatropha—a crop whose seeds produce oil that is used to create biodiesel—was introduced to Kenya several years ago on the basis that it could grow on arid lands and hence provide economic activity in otherwise unproductive areas. However, time has shown that while jatropha can indeed grow on poor land, the results are similarly poor, and it has consequently become less popular (Khatun, 2013).

As shown in Figure 5.1, the potential for feedstock production varies dramatically across Kenya (African Centre for Technology Studies, 2010). The coastal, central, and western regions are suitable for a large number of crops, while the north, east, and southwest could only support a few. Besides geographic limitation, there are also significant regulatory barriers for SMEs thinking of entering this market. Much of Kenya's land has no formal owner. This lack of land tenure restricts development: proposed developments face opposition owing to disputes over access rights and furthermore people are unwilling to make long-term investment in land without guarantee of ownership.

Figure 5.1. Number of biofuel crops suitable per scene



Source: ACTS, PISCES and UNEP, 2010.

Cogeneration or combined heat and power (CHP)

Sugar companies have the opportunity to produce two types of bioenergy from waste sugar material: bioethanol from molasses; and cogeneration using bagasse. Inefficiencies in the Kenyan sugar industry mean that prices are about twice the international level (FAO, 2012). Market protection currently provided by the Common Market for Eastern and Southern Africa (COMESA), which limits sugar imports through tariffs and quotas, will expire in 2014 and the resulting market liberalization could result in a flood of imports driving domestic prices down by as much as 25 percent (FAO, 2012). Therefore companies will need to find methods of cost reduction and income diversification, to which bioethanol and electricity production could both contribute (Mumias Sugar Company, 2013).

There is also potential for adoption of a scheme common to Brazil where sugar and bioethanol production can be altered according to relative prices, in order to maximize income (Hunt, 2013). Bioenergy from sugar residues—through bioethanol or cogeneration—could therefore become more attractive, expanding these markets.

Cogeneration plans have been incorporated into four of the seven large Kenyan sugar companies, but bioethanol production has not received the same level of take-up. Development in this area has so far been limited because of high investment costs, uncompetitive price mechanisms, limited technology, and a weak legal and regulatory framework. However, Kenya Sugar Board newly requires all sugar mills to include ethanol and electricity production in their operations within 24 months (Business Daily Africa, 2013). This condition is currently met only by Mumias Sugar Co., the largest sugar producer by volume. These factors could provide the necessary incentives to kickstart the bioethanol market, creating potential for SMEs in ethanol retail and ethanol-related products and appliances.

The diversification of sugar companies into ethanol and electricity production has impacted the supply chain of companies that solely produce ethanol.

Spectre International, also known as Kisumu Molasses, used to source 60 percent of its material from Mumias Sugar Co., for whom it was a waste product. However, since Mumias opened its own distillery, this supply has been greatly reduced. As a result, Spectre was forced to close for several weeks in early 2013 until new suppliers could be found. Spectre now imports molasses from Kakir and Kagera in Uganda and Tanzania respectively (The Star-Kenya, 2013).

Innovation opportunities in the Kenyan bioenergy market

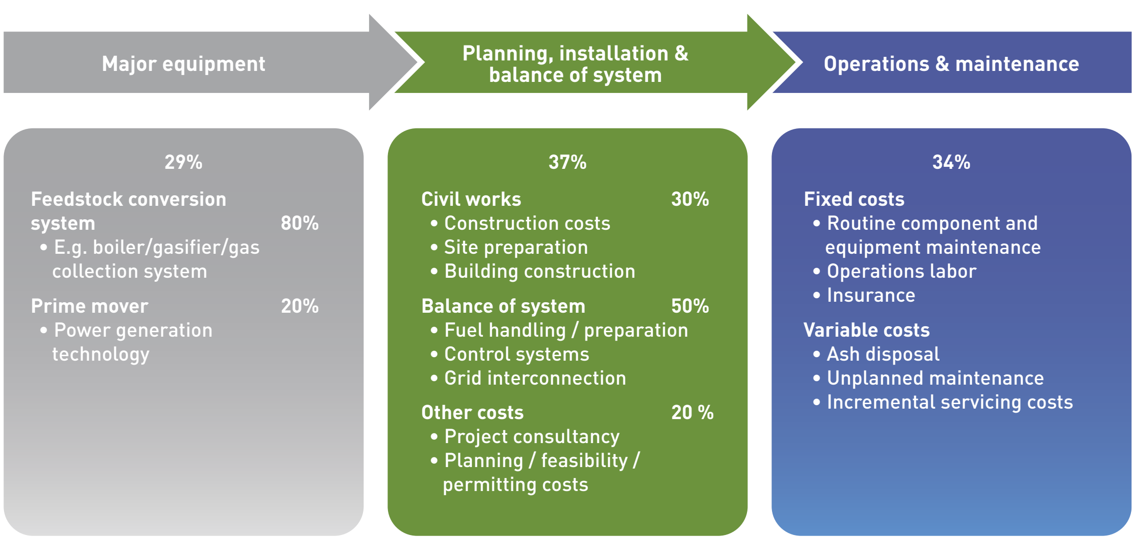
There are strong innovation opportunities in bioenergy through the entire value chain (see Figure 5.2), such as maximizing the yields of dedicated energy crops (particularly those on marginal land), which would reduce costs and relieve pressure on land use. There are also significant innovation opportunities in improving the technologies used to convert feedstocks and waste so that it can be done more reliably, efficiently and at greater scale (Carbon Trust, 2012b). Much of this innovation might be done abroad, however there may be opportunities for local firms to customize these technologies to local conditions and needs.

Innovative financing arrangements are needed in bioenergy to open up the market to potential customers with limited upfront capital particularly on the domestic and small business side. Takamoto Biogas is one such company trying to turn the lack-of-capital barrier into an opportunity. Accessing low-cost finance is also important for larger-scale projects, especially in a highly competitive cost environment. Innovation is also needed to improve the degree of technical quality assurance around the performance of particular technologies, once confidence in the technology is established developers and financiers will be more willing to invest as the technology risk is lower.

The bioethanol industry also has opportunities for SMEs in appliance production and small-scale fuel retail, as large companies such as Spectre prefer to sell in bulk to vendors. This market should expand because of the push factors examined above, including the removal of trade barriers and new policies requiring ethanol production. Overall, innovation in all segments of the value chain, as well as in sales, service, and financing, has a key role to play in supporting the deployment of bioenergy in Kenya.

In addition to innovation opportunities, there are support structures in place to drive clean-technology growth particularly among SMEs. Nontraditional financing and NGO support is available to assist preliminary entry into the market. For example, the Visionary Empowerment Program offers microfinance to small-scale farming and industrial businesses. It works with the Kenya National Biogas Program to fund construction of biogas technology (The Guardian, 2011). Further, the market for the Kenya Clean Jiko (KCJ) stove (an efficient cooking stove) was initially supported by NGOs, but now runs commercially

Figure 5.2. Bioenergy value chain (excluding feedstock)



in its own right (Hunt, 2013). The Kenya CIC also provides financing and incubation support to clean technology SMEs.

To encourage domestic deployment of renewables, the government recently applied a zero-rated import duty on renewable energy technologies and removed VAT from related equipment and components. This could reduce costs for SMEs but the availability of cheap imported systems could make it hard for domestic producers of clean technology equipment to compete.

SMEs often try to source from local suppliers to keep costs down (Anjarwalla, 2013), which in turn presents opportunities for other local SMEs. For example, Kenyan company CYPRO Biogas is working with Polytanks (a Kenyan business in molded plastic products) to produce an innovative plastic tank for them to distribute as part of their business (Anjarwalla, 2013).

BOX 5.4. *info*Dev's Kenya Climate Innovation Center

The Kenya Climate Innovation Center (Kenya CIC) was the first CIC to be established by *info*Dev's Climate Technology Program at the World Bank. Since its launch in September 2012, the Kenya CIC continues to support a growing network and cluster of climate innovators and entrepreneurs.

It aims to provide holistic, country-driven support to accelerate the development, deployment, and transfer of locally relevant climate and clean energy technologies. The Kenya CIC provides incubation, capacity-building services and financing to Kenyan entrepreneurs and new ventures that are developing innovative solutions in energy, water, and agribusiness to address climate change challenges. Its priority sectors are off-grid renewable energy, water management and purification, biofuels, and climate-smart agriculture. It is also a key part of the government of Kenya's National Climate Change Action Plan.

The Kenya CIC has supported more than 70 clients and has provided more than $250,000 in proof-of-concept grants as of November 2013, while offering direct services and broader training sessions on accessing carbon finance and intellectual property rights, each done in partnership with the World Intellectual Property Organization (WIPO). The KCIC aims to further grow its client base and will expand its services with a seed capital investment facility.

Kenyan Clean Technology Firm Survey Results

The clean technology market opportunity analysis shows that as much as $290 billion will be invested across 11 clean technology sectors over the next decade in East Africa.[20] The analysis was conducted at the regional rather than country level so does not estimate Kenya-specific investment, however it is expected that a significant portion of the regional investment would be focused on Kenya.

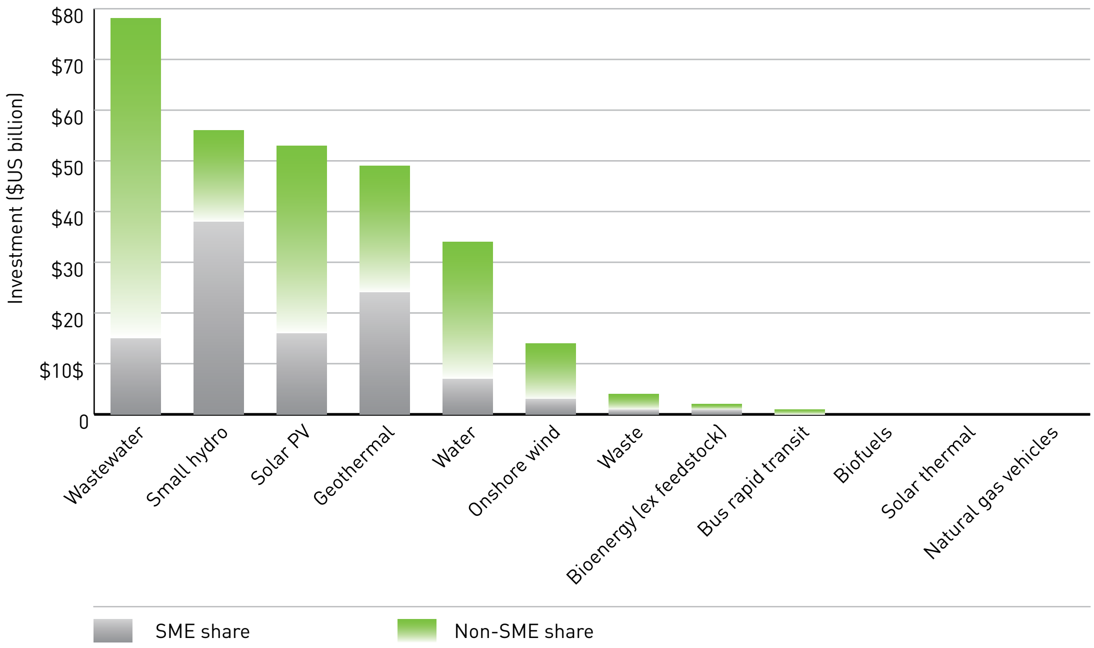
In East Africa, wastewater, small hydro, solar PV, geothermal, and water were among the top five clean technology sectors (see Figure 5.3), and SMEs would find the best opportunities in small hydro and geothermal sectors (see Figure 5.4). Similar to other regions, SMEs are expected to be most active in planning, installation, balance of system and O&M segments of the value chain. In this section, these estimates are compared to the results from the survey of 50 clean technology firms in Kenya.

The survey suggests that a large majority of the firms are active in renewable energy, including solar: 87 percent of firms said they worked in renewable energy, 46 percent are in energy efficiency, 28 percent in sustainable agriculture, and 26 percent in waste management and purification (note that firms could select more than one sector). These commercial activities largely reflect the areas of greatest opportunity that were identified through the market sizing study, and may reflect the fact that firms are choosing to get involved in sectors that are growing.

The survey also revealed that the Kenyan clean technology SMEs are working throughout the value chain: over 80 percent of firms work in design, and/or consulting and over 70 percent work in installation, operations and maintenance,

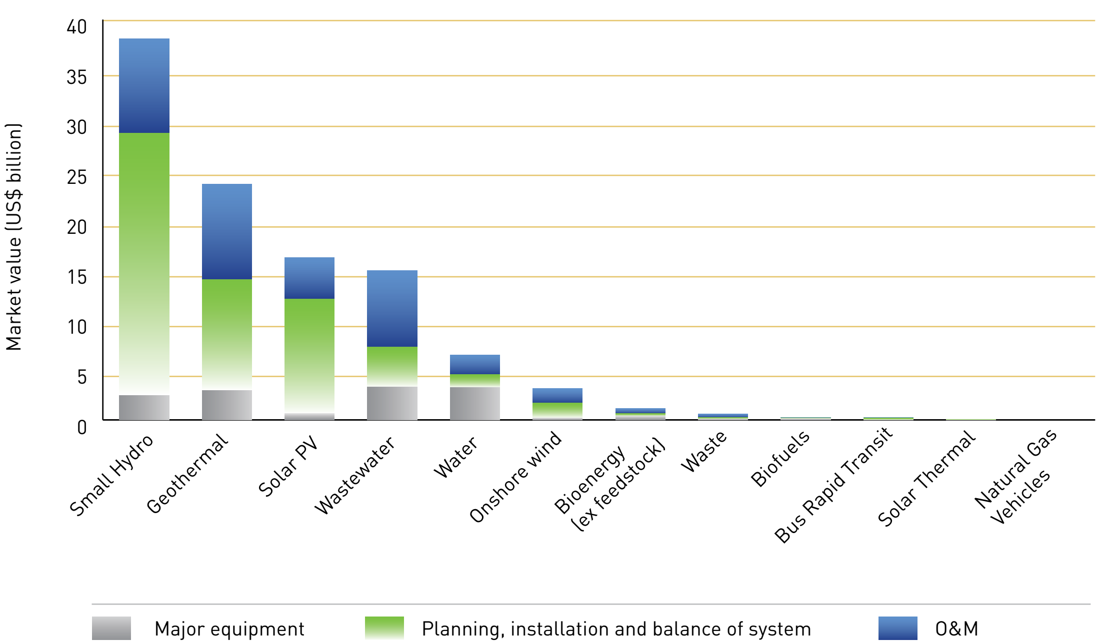
20 Based on authors' analysis, which assumes that the planned investment by the Kenyan government is realized in full. Actual investment might be lower than suggested if there are significant delays or changes to the proposed investment plans.

FIGURE 5.3. Investment in clean technology in East Africa: SME and non-SME share ($ billion)



Source: Authors' analysis.

FIGURE 5.4. SME share of East African clean technology market by value chain segment ($ billion)



Source: Authors' analysis.

manufacture and assembly. Compared to Indian, firms in Kenya are younger and spread throughout the value chain, at least for now as they find their footing.

The surveyed firms were also international, and significantly more international than non-clean technology firms in Kenya; 25 percent of non-clean technology firms in Kenya export and 78 percent of their sales are domestic (World Bank, 2013). Of the clean technology firms surveyed, 52 percent had customers overseas (mostly in Africa, and some in Europe and North America). Nearly 80 percent had suppliers based in a foreign country, unsurprisingly many from China (83 percent), followed by Europe (53 percent) but also from India and other parts of Africa (about 30 percent each).

Overall, the firms expressed a high level of optimism about the current and future Kenyan clean technology market: 96 percent of the firms indicated that they were either very or fairly confident about their business environment in Kenya. The surveyed firms' historical and projected growth also showed promising signs: 91 percent experienced sales growth in 2013 and nearly 70 percent of the firms purchased fixed assets in 2013, reflecting their willingness to invest and suggesting their confidence and optimism about the market.

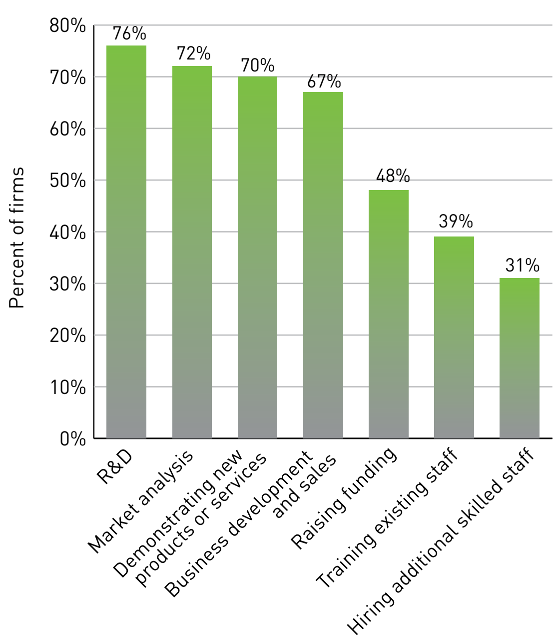
The survey shows that Kenyan clean technology firms regard themselves as innovators. Over the past two years, about 85 percent of surveyed firms introduced new or significantly improved clean-technology products or services. There is also a noteworthy range of activities undertaken by clean technology SMEs to grow or enhance their clean technology business, as shown in Figure 5.5.

While a promising market opportunity, there are also barriers to the rapid scale-up and deployment of bioenergy in Kenya. The top barriers faced by surveyed clean technology firms in Kenya are shown in Figure 5.6.

In common with surveyed firms in India, the barrier most commonly cited by respondents was access to finance. A further 85 percent of those surveyed indicated they plan to raise funding in the next two years, making the issue of access to affordable finance a priority. Limited capital creates the need for credit, but this is often unaffordable or simply unobtainable. Kenyan banks are reluctant to loan to people without financial records, and their interest rates are high, for example, interest rates are in the region of 18 percent (Anjarwalla, 2013). Interviews with firms suggested that there is substantial interest from potential foreign investors, especially following the opening of the Kenya CIC, but this is not being realized as the pipeline of opportunities currently do not meet their standards. There are further opportunities for funding through grants, but these are very competitive (Anjarwalla, 2013). As a result, ventures are commonly funded informally using money from friends and family (Khatun, 2013). There is also a high level of reliance on international donors as many businesses cannot afford to operate unsupported. This lack of finance restricts entrepreneurial development. For example, one Nairobi entrepreneur receiving incubation support from the Kenya CIC, manufactures charcoal briquettes in a process that involves drying out charcoal dust in the sun, which is vulnerable to Nairobi's unpredictable rain. A solar dryer is needed but the entrepreneur cannot receive credit as he has no financial record (Anjarwalla, 2013).

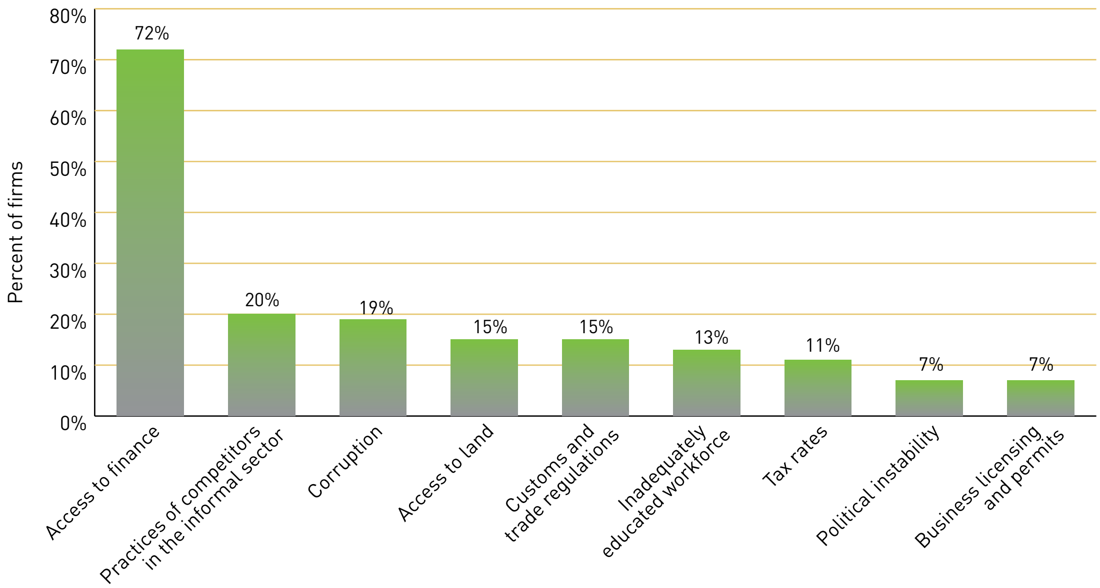
Kenyan private companies from a range of sectors surveyed in 2013 indicated that practices in the informal sector was the biggest barrier they faced, with corruption ranking as the second biggest barrier. While not at the top of their list of barriers,

FIGURE 5.5. Innovation activities undertaken by clean technology SMEs in Kenya



Source: Survey of clean technology firms in Kenya undertaken in July and August 2013.

FIGURE 5.6. Most common barriers faced by clean technology SMEs in Kenya



Source: Survey of clean technology firms in Kenya undertaken in July and August 2013.

the surveyed clean technology firms (20 percent) were similar to their private sector counterparts (24 percent) in identifying the practices of the informal sector as significant. Corruption and access to land were also significant barriers for clean technology firms. A lot of clean technologies require access to land, which may underlie this concern. Corruption is prevalent in Kenya, and Kenya regularly scores badly on transparency international's corruption perception index, ranking 139 out of 176 countries. Indian firms also indicated corruption as a significant barrier, although India is ranked 45 countries ahead of Kenya on the index. One example of corruption impacting on the bioenergy sector is the extraction of "tariffs" by police. Historically it was illegal to produce and transport charcoal, so biomass is still the target of police checks, often solely to extract illegal tariffs on transporters, who are not sufficiently knowledgeable of the change in law to question it (Hunt, 2013).

The bioenergy sector in and of itself suffers from some specific obstacles (see Table 5.1). Because much of it relies on new technology, it suffers from a 'chicken and egg' problem, whereby it is hard to get a venture off the ground because of a codependency. For example, the ethanol appliance industry is currently limited, as there is little ethanol available to use, but meanwhile there cannot be a market for ethanol without the availability of stoves with which to use it. Similarly, a biofuel processing plant requires feedstock, which will not exist without a market to sell to. This increases the capital intensity of new biofuel development as the two often need to be created simultaneously.

Because much of bioenergy requires the collection and transport of large volumes of biomass to get workable economies of scale, Kenya's poor infrastructure and numerous remote communities can make scale-up difficult. For example, biofuel production can be hard to develop from a pilot to a commercially viable business because of the fragmented nature of Kenyan farming, as feedstock collection from a large number of small farms incurs logistical difficulties and large expense (Anjarwalla, 2013).

There are also human capital constraints. There is a skills gap in Kenya, and many Kenyans lack the training necessary to turn an idea into a successful business. Many are unable to compose investment proposal documents, such as technical reports and financial projections, thus further reducing their chances of obtaining credit. Support is largely unavailable from banks, which generally do not engage with their clients in business activities such as sales and marketing (Anjarwalla, 2013).

Photo: Stephan Bachenheimer / World Bank.

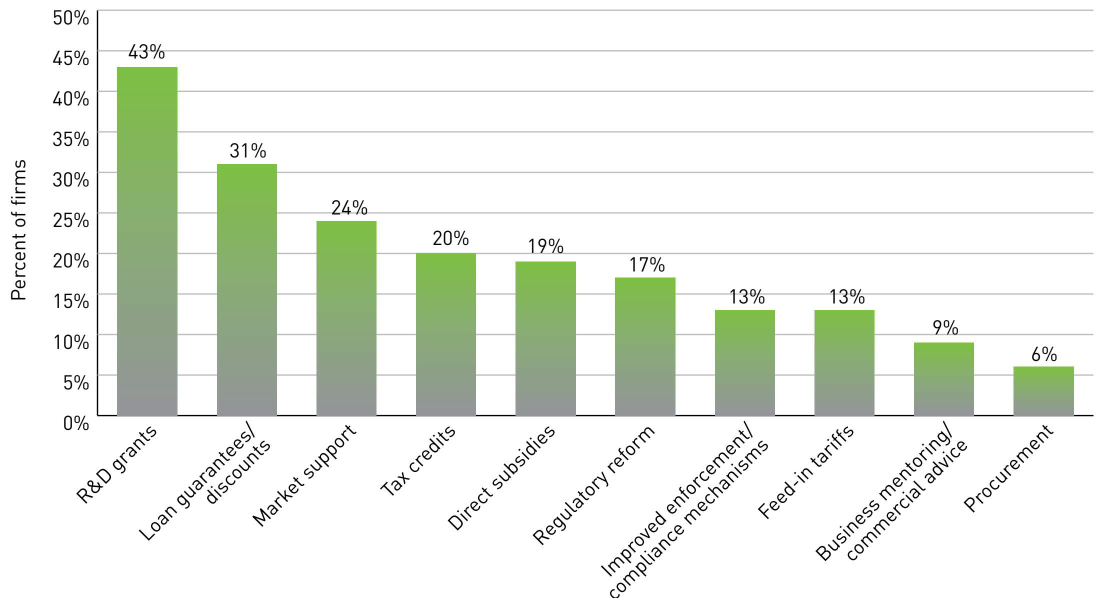
There is also inequity in the awareness of and access to support for SMEs. The fact that it is cheaper to reach those who are located in more accessible places means rural and remote areas are at an immediate disadvantage (Hunt, 2005). For example, owing to its physical presence in Nairobi, the Kenya CIC has a Nairobi-heavy portfolio of businesses in incubation (Anjarwalla, 2013). There is also a gender imbalance: 80 percent of the entrepreneurs supported by the Kenya CIC are men, perhaps resulting from the traditional patriarchal culture.

The SMEs surveyed highlighted areas where they could use government support in growing and overcoming some of the key barriers they face with the top three areas relating directly to accessing capital (see Figure 5.7). Forty-three percent thought the government could provide more research and development grants, 31 percent

TABLE 5.1. Barriers and opportunities faced by Kenyan SMEs

	Main barrier	Main opportunity
Industry-specific		
Domestic biogas	Market is restricted by requirement for two standing cows, water usage, and large installation cost	Innovative financing mechanisms such as the pay-as-you-go system
Industrial biogas	Upfront capital investment is required	Demand from companies with large quantities of organic waste, such as dairy and sugar
Ethanol	Upfront capital investment is required	Market set to expand as new legislation forces sugar companies to diversify into ethanol production; opportunity for SMEs in distribution and the appliance market
Crop-based biofuels	Land tenure and food security issues result in dramatic opposition to proposed development; uncertainty over potential due to lack of a published biofuel policy	Improvement in crop efficiency on marginal lands
Market-wide		
Skills	Lack of business skills; inequity in access to support	Incubation and finance support from the Kenya CIC and other government and donor programs aimed at promoting the SME sector
Markets	Poor infrastructure impedes transportation	Businesses looking to source locally to keep costs down

FIGURE 5.7. Areas for government support identified by clean technology SMEs in Kenya



Source: Survey of clean technology firms in Kenya undertaken in July and August 2013.

pointed to loan guarantees or discounted financing, and 19 percent to direct subsidies. Not far behind at 17 percent was improved regulatory reform, which could help address the obstacle related to practices of the informal sector identified in the survey and barriers related to land tenure.

The survey also identified areas of support SMEs sought from organizations outside of government, which differed from the support they required from the government. SMEs identified support in networking and the development of business skills in marketing and sales as key areas where organizations like the Kenya CIC could assist.

Conclusion

The clean technology market in Kenya is relatively nascent and a wave of policies and programs are beginning to translate into market opportunities for SMEs and entrepreneurs. The most promising opportunity in the sector appears to be in the production of industrial-scale biogas, in particular for companies in industries producing large volumes of organic waste, such as dairy or sugar. The bioethanol market also has potential for growth as sugar companies look to income diversification for financial and regulatory reasons. Bioethanol production in itself is not a large SME opportunity, but linked markets including distribution and appliances could provide an opportunity for SMEs. Barriers to these opportunities, however, do exist, especially involving access to finance, the practices of the informal sector, and corruption.

According to the survey of clean technology SMEs in Kenya, firms are optimistic about the market and are active in a variety of innovation-oriented activities. However, they indicate the need for financial assistance for both seed and growth capital, as well as general business support programs. Removing key barriers and providing targeted policy and business support would provide opportunities for additional industry growth and SME participation.

Chapter 6

Case Study: Climate Smart Agriculture in India and Kenya

Main Points

- This case study examines climate-smart agriculture (CSA) in India and Kenya, and highlights the differences between agriculture and other clean-technology sectors and the main challenges facing the two countries.
- Agriculture is a major employer and source of economic activity in developing countries but faces many environmental, institutional, financial, and behavioral challenges that are exacerbated by climate change and rural poverty.
- Climate-smart agriculture is an approach that aims to integrate social, economic and ecological objectives to increase agricultural yields, boost profits, reduce local pollution, address poverty, enhance climate resilience and reduce greenhouse gas emissions.
- CSA differs from other clean technology sectors because it tends to rely on donor and government involvement and depends heavily on behavior change, education, and institutional reform, but nevertheless represents a commercial opportunity for SMEs.
- Drip irrigation, food storage, and agroforestry are three innovative agricultural activities profiled in this case study; there are many other SME opportunities that align with CSA goals.

To address growing challenges, society will depend on a productive agricultural system that is economically, socially, and environmentally sustainable. Agriculture underpins the livelihoods of billions of the world's poorest, employing 2.6 billion people, most of whom are smallholders. A growing global population requires agricultural productivity to increase substantially over the coming decades, but current agricultural practice is putting unsustainable demands on the natural environment. Increasing the use of agricultural inputs is delivering diminishing returns in many parts of the world, and practices that were promoted throughout the Green Revolution are turning out to be unsustainable in the longer term. These challenges, together with the rapidly changing environmental conditions caused by climate change, are putting serious pressure on agricultural productivity and the livelihoods of billions of people.

CSA is an approach that aims to integrate social, economic, and ecological objectives to increase agricultural yields, boost profits, reduce local pollution, address poverty, enhance climate resilience, and reduce greenhouse gas emissions. The approach combines proven agricultural techniques with innovative farming practices, and addresses multiple local and institutional barriers to change in order to improve the sustainability of agriculture (FAO, 2013).

Institutions like the World Bank and the International Fund for Agricultural Development (IFAD) are leading the way in approaches to sustainable development that integrate the fields of agriculture, water management, forests,

Photo: Edwin Huffman / World Bank.

food security, and socioecological systems. While climate-smart agriculture is for the most part being led by governments, bilateral, and multilateral institutions, it is also generating commercial opportunities for SMEs in Kenya, India, and other countries around the world.

This case study examines the role of agriculture in Kenya and India and documents the challenges facing the sector in those countries. It discusses why agriculture is different to other clean technology sectors, and describes how CSA is an approach that is starting to overcome the unique barriers facing it. India and Kenya's policy frameworks are explained to show how they are promoting and implementing CSA practices. Finally, three different potential SME activities are described to illustrate the ways in which CSA can create opportunities for entrepreneurs in developing countries.

Importance of Agriculture Sector in India and Kenya's Economies

Agriculture underpins employment in both India and Kenya, and contributes significantly to economic productivity. The agricultural sector employs 51 percent of the Indian workforce and makes up about 15 percent of GDP. The numbers are even more striking in Kenya, where agriculture employs 75 percent of the Kenyan workforce and makes up 51 percent of GDP (Feed the Future, 2013).

India is a regional leader in farming and animal rearing. India is the world's largest producer of milk, pulses, and spices, and has the largest cattle herd of buffalo.

India has 195 million hectares under cultivation, of which roughly 63 percent is rain fed, with the remainder irrigated. It has the world's largest area under cultivation for wheat, rice, and cotton, and is the second largest producer of wheat, rice, cotton, sugarcane, farmed fish, sheep meat, goat meat, fruit, vegetables, and tea (World Bank, 2012a).

Climate-smart agriculture is generating commercial opportunities for SMEs in Kenya, India, and other countries around the world.

Kenya has a much less bountiful natural agricultural resource endowment than India. Its soils are less suitable for crops and livestock, and tend to be deficient in nitrogen and phosphorus, and occasionally potassium, the three key ingredients of fertilizer. Rainfall is low, variable, and unreliable, which leads to limited organic buildup and poor soil fertility and structure. As such, only about 15 percent of its land has the soil and precipitation characteristics to make it agriculturally appropriate, and only about 7 percent of land is of high quality (FAO, 2006). Just less than 10 percent of Kenya's land as of 2011 is being used for agricultural purposes (World Bank, 2011b).

With such characteristics and the subsistence nature of most of its farmers, Kenya is understandably not the regional leader in many agricultural products. Nevertheless, it leads the African continent in tea production and is a large exporter of coffee. It is also well known for floral exports, as well as other horticultural products including green beans, onions, cabbages, snow peas, avocados, mangoes, and passion fruit (Horticultural Crops Development Authority, 2013).

Both the Indian and Kenyan governments acknowledge the enormous importance of agriculture as it relates to both economic performance and the livelihoods of the country's most disadvantaged population groups. They also recognize the threats to agriculture caused by climate change. In 2013 alone, sudden and severe rains caused extensive flooding in India's north, while severe drought struck in the east of the country. A major drought across the entire East African region in 2011 devastated agricultural output and led to regional instability as people fled from neighboring countries into Kenya and staple food prices soared.

Both countries suffer from soil degradation, water stress, crop productivity problems, the need to feed a growing population, and increasingly severe threats from climate change. Many agricultural products in India and Kenya are being grown at or close to their maximum heat tolerance. Sustained heat waves can devastate wheat, rice, maize, and other crops, and negatively impact upon the productivity and reproduction of higher-yielding cattle species compared to more resilient but less productive local varieties.

Given India's size and the diversity of its climatic zones (ranging from arid to tropical wet to humid subtropical), responses to climate impacts are necessarily varied and regionally specific. Kenya's rural, poorly educated, impoverished, and fast-growing population limits its adaptive capacity, which exacerbates the agricultural impacts of climate change. Together, the countries face some of the same agricultural challenges, but also have different characteristics that require bespoke agricultural interventions to be tested, disseminated and adopted at large scale.

BOX 6.1. Solar pumps make irrigation accessible

Irregular and insufficient rainfall is a challenge to farmers who must pump water onto their fields manually or with the help of expensive and polluting petrol or diesel pumps. SMEs like **Future Pump Ltd**, a Kenyan company, are helping to solve that problem with innovative solar powered pumps that can irrigate half an acre per day with no manual labor or fuel costs. The initial investment of around $400 can be recouped in 1-2 years compared to the ongoing running costs of diesel or petrol engines, and higher yields from more productive crops further boosts the business case for these pumps. Future Pump Ltd. is working with Kenya Climate Innovation Center to get business support, introductions to distributors and sales partners, and linkages to potential investors for business acceleration.

Agriculture is different than other clean technology sectors

Unlike renewable energy or cleaner transportation options, improving agricultural practice depends heavily on behavior change, education, and institutional reform rather than on technological interventions. It is also almost exclusively driven by donor agencies and governments, and tends not to be as suitable for public-private partnership as other clean technology sectors.

While agriculture has been practiced for thousands of years, sustainable agriculture that enhances climate change resilience and increases the intensification that is required to feed the world's growing population is a more nascent area of study. Newer sustainable farming practices reimagine the agricultural paradigm that propelled countries like India through the scarcity challenges of the 1970s. At that time, the Green Revolution addressed the challenge of population growth outstripping agricultural productivity gains through agricultural intensification practices such as mass mechanization, the introduction of pest and disease resistant crop varieties, and subsidies for agricultural inputs like seed, fertilizer, pesticide, and irrigation infrastructure.

While the Green Revolution has been an effective intervention that significantly improved yields, its limitations are becoming clear. Mechanized ploughing has accelerated soil erosion and land degradation. Excessive use of fertilizers and pesticides has degraded soil quality, increased pest resistance, and polluted waterways and groundwater sources. Monocropping has reduced soil fertility and biodiversity, and has exposed farmers to ecological and economic threats. Excessive and continual irrigation has led to soil salinization and unsustainable withdrawals from aquifers (IFAD, 2012). The negative environmental externalities from these kinds of agricultural practices coupled with the accelerating impacts of climate change are making it more difficult for today's farmers.

BOX 6.2. Drying food to cut post-harvest losses

Ineffective and inadequate food storage systems lead to postharvest food losses, foregone revenue, and wide fluctuations in the market price of harvested produce because of seasonal gluts and undersupplies. Drying food for storage can effectively address these problems. **Azuri Health Ltd** is a Kenyan SME that uses solar driers to treat and preserve food bought from farmer groups, including mangoes, pineapples, bananas, sweet potato flour, and nutri-porridge.

Conventional driers tend to rely on costly fossil fuels or electricity, and generate greenhouse gas emissions, but Azuri's technology has lower operating costs and is emissions-free. Azuri has sought advice from Kenya Climate Innovation Center to address several business and technical challenges including product development and information on international markets.

Likewise, the speed and severity of climate-related changes is a challenge for governments, many of which lack the funding and institutional capacity to disseminate better agricultural practice. Their responses to these multiple agricultural challenges are often under-researched and poorly communicated.

Setting this against a backdrop of extreme vulnerability exacerbates the challenge. Poor subsistence farmers tend to either cling to traditional agricultural practices, which are becoming increasingly inappropriate given the changing climate, or must unlearn some of the farming practices that government agricultural extension services have been disseminating, which are delivering diminishing returns today and are proving to be unsustainable in the long term.

Subsistence farmers with no savings and no public safety net are understandably risk-averse. They are reluctant to experiment with new practices that may require more than one harvest season before showing dividends, have strained human, financial, and environmental capital, and are suspicious of agricultural extension services whose message is changing. This issue of trust is another barrier faced in changing agricultural practices that other clean technology sectors, like public transit or water, wastewater, and solid waste management solutions do not face.

Climate-smart agricultural solutions tend to have more difficulty attracting finance than other sectors too, especially in the context of carbon sequestration. Sequestration benefits from agriculture are more difficult to measure and verify than traditional abatement opportunities in energy, industry, or transport, and may be easily lost if behavior change is not sustained in the longer term. And climate resilient agricultural activities often include both mitigation and adaptation outcomes, whereas many climate funds tend to focus on one or the other.

Understanding what constitutes better agricultural practice is not always straightforward, either. Whereas, for example, well-designed feed-in tariffs are almost guaranteed to accelerate the deployment of renewable energy and can be easily scaled, agriculture's site specificity means that it is often ineffective to standardize and scale up uniform solutions. Moreover, existing agricultural policies and programs often promote the very practices that are degrading ecological services. Moving towards more resilient agricultural policies and programs means that policy makers and their rural and often poor and undereducated constituencies need to reverse the spread of recently promulgated policies and practices.

Scaling is also a challenge because of the number of farmers that must be reached. There are about 2.6 billion farmers in the world—about 40 percent of the global population—most of whom are smallholders. The sheer number of people involved in agriculture makes large-scale dissemination of best practice a daunting challenge, and also makes transaction costs too high for farmers to be involved in climate finance schemes.

For all these reasons, sustainable agriculture faces a multitude of barriers that other clean technology sectors do not. Overcoming these barriers, though, is fundamental to enhancing the food security and livelihood opportunities of billions of people, and is needed to ensure that the planet's growing population can be fed.

CSA Is Beginning to Deliver Dividends

Despite these challenges, CSA is starting to deliver results. Donor agencies like IFAD and branches of the World Bank Group have been working with government partners to develop approaches to CSA that are paying real dividends, not only in terms of higher yields and profit, reduced local pollution, poverty reduction, and enhanced climate resilience, but also in terms of greenhouse gas abatement.

Indeed, mitigation and adaptation are linked in the World Bank's definition of CSA, which sees it as an activity that "seeks to increase sustainable productivity, strengthen farmers' resilience, reduce agriculture's greenhouse gas emissions and increase carbon sequestration. It strengthens food security and delivers environmental benefits. Climate-smart agriculture includes proven practical techniques—such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing and improved water management—and innovative practices such as better weather forecasting, more resilient food crops and risk insurance" (World Bank, 2013e).

CSA works when approached from a multiple-benefits perspective. Such an approach aims to address the complex links to other socioecological phenomena, like deforestation, land degradation, water stress, food insecurity, poverty, and gender discrimination. Understanding these interconnections through deep vulnerability assessments, the use of climate modeling, and an understanding of integrated landscape and watershed dynamics is the first step to developing a CSA plan.

CSA plans integrate a host of approaches, including maximizing the use of natural processes and ecosystems; reducing external inorganic inputs and waste; diversifying production and ensuring crops and livestock are cultivated in locally appropriate proportions; and mixing new technologies with traditional knowledge (IFAD, 2012).

Integrated vulnerability assessments indicate how, when, where, and in what quantity certain interventions can generate multiple benefits. They can be done on different scales and in different landscapes that have various assets but face multiple threats. Once these socioecological diagnostics are complete, appropriate interventions can begin.

The fundamental underpinnings of CSA already exist and are being successfully applied in many countries. They include interventions such as terracing and leaving crop residue cover to prevent water and wind erosion and enhance soil retention; zero or minimum tillage combined with the application of mulch, manure, or other organic fertilizers to improve soil quality and structure; and fallowing and crop rotation, including the use of leguminous nitrogen-fixing varieties, to enhance soil fertility. Interventions can also be more technical, such as precision agriculture to optimize inputs using sensors and software; water conservation and reuse activities like drip irrigation; and biotech improvements to introduce drought- and pest-resistant varieties and increase yields.

Animal systems also factor in. Fodder crops can be grown and stall-fed to livestock in order to intensify livestock production while freeing up rangeland for other productive purposes. Better yielding livestock varieties can also be introduced.

Agroforestry is another intervention, where planted trees improve microclimates; provide shade to crops and livestock; enhance water retention in soils; and bring underground nutrients to the surface through the growth, shedding, and decomposition of leaf litter. Trees can also provide an opportunity for income diversification and asset accumulation as they grow and produce fuel wood, construction materials, or food like nuts and fruit.

These interventions help to improve crop yields, lead to enhanced biodiversity, improved climate resilience and asset diversification, pollution reduction, and reduced reliance on expensive agricultural inputs. They also fix carbon through sequestration in soils and standing biomass, and can help minimize the release of greenhouse gases from inorganic fertilizers, slash and burn techniques, and enteric methane emissions from cattle. However, many interventions focused on behavior change do not obviously lead to significant opportunities for SMEs, and highly technical interventions may be inappropriate for a typical rural farmer. CSA activities do, however, make the livelihoods of farmers (many of whom are SMEs in their own right) more secure.

Government Policy Is Supporting the Promulgation of CSA

Like the Solar Mission, India's National Mission for Sustainable Agriculture was released in 2010, two years after the NAPCC (Department of Agriculture and Cooperation-India, 2010). Implementation of this mission falls to the Department of Agriculture and Cooperation, which is part of India's Ministry of Agriculture. Recognizing the threats to agriculture posed by climate change, the mission seeks to "transform Indian agriculture into a climate resilient production system through suitable adaptation and mitigation measures in the domain of crops and animal husbandry"(Department of Agriculture and Cooperation-India, 2010).

The breadth of activities that fall under CSA makes this mission more of a list of recommendations than a targeted set of interventions. To provide some structure, however, sustainable agriculture is framed using ten main objectives (Press Information Bureau- Government of India, 2013):

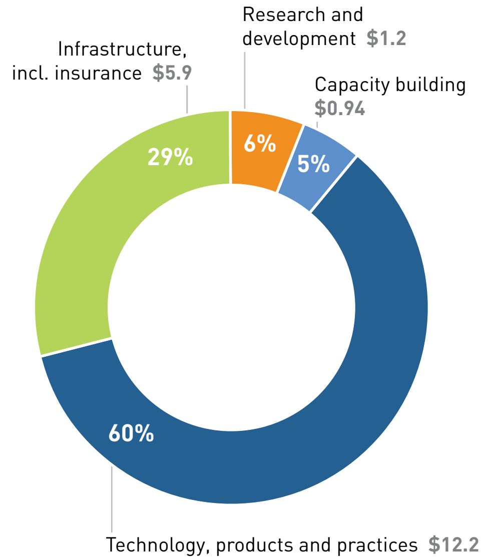
1. Improved crop seeds, livestock and fish culture
2. Water efficiency
3. Pest management
4. Improved farm practices
5. Nutrient management
6. Agriculture insurance
7. Credit support
8. Markets
9. Access to information
10. Livelihood diversification

Under each objective, activities are qualitatively listed and grouped into four "functional areas." The areas and their respective budgets are shown in Figure 6.1.

It is worth noting that half of the budget under "Technology, products and practices" is earmarked for water use efficiency, including micro-irrigation and efficient water management. Water use and water conservation also feature in the other functional areas, and naturally overlap with the National Water Mission.

What is surprising about this mission's multiple objectives is the limited degree to which the biggest sources of agricultural GHG emissions

FIGURE 6.1. Functional areas and their budgets ($ billion)



Source: Department of Agriculture and Cooperation-India, 2010.
Note: Exchange rate, World Bank 2008-2012 average http://data.worldbank.org/indicator/PA.NUS.FCRF

are addressed. Deep in chapter six of the mission document,[21] three key mitigation measures are mentioned (changing livestock feeding practices; further adopting the System of Rice Intensification; and soil-related measures including reduced tillage and using improved crop varieties that exhibit better carbon sequestration), but they are only mentioned in passing and without any specific plan for action.

Overall, the National Mission for Sustainable Agriculture is a broad set of aspirational objectives that as of yet are not specific, measurable, or time-bound. They aim to ameliorate a wide variety of physical, behavioral, and institutional obstacles to a more productive and more sustainable agricultural sector, but do not specifically target the areas of greatest agricultural emissions.

Kenya's ten-year Agricultural Sector Development Strategy was also released in 2010 and includes recommendations that could enhance the resilience of the agriculture sector in the face of climate change. It recognizes that changes are

21 See "National Mission For Sustainable Agriculture: Strategies for Meeting the Challenges of Climate Change." Department of Agriculture and Cooperation Ministry of Agriculture New Delhi, 2010. http://www.nicra-icar.in/nicrarevised/images/Mission Documents/National Mission For Sustainable Agriculture-DRAFT-Sept-2010.pdf

needed in the policy, legislative, and institutional space, as well as in the field through education and awareness-raising activities and local vulnerability assessments (Agricultural Sector Development Strategy-Kenya, 2010). Specific interventions were outlined in more depth in Kenya's updated National Climate Change Action Plan, which was released in 2013 (National Climate Change Action Plan 2013-2017-Kenya, 2013). The plan includes interventions for agriculture, and livestock and pastoralism.

In agriculture, the plan aims to promote irrigation and conservation tillage; develop weather-indexed crop insurance schemes; and provide support for community-based adaptation schemes including the provision of drought-resistant seed and agricultural extension services that aim to educate farmers about climate risks. In terms of livestock and pastoralism, the plan recommends breeding heat-tolerant animals; promoting vaccination campaigns; ensuring a safe and adequate water supply for both animals and people; and providing insurance schemes.

Kenya recognizes the triple wins that climate-smart agriculture can deliver from enhanced carbon mitigation, improved adaptation benefits, and higher productivity and profits. It is currently developing policies and approaches to implement CSA on a large scale, and does not have to overcome deeply institutionalized policies and practices that are not necessarily congruent with CSA, as India does.

The government is active in moving its CSA program forward with the help of development groups such as CCARS (the Research Program on Climate Change, Agriculture and Food Security), which is supported by CGIAR (the Consultative Group on International Agricultural Research). The group is working to build consensus on the priority actions related to agriculture that are proposed in the NAPCC so that they can be piloted and ultimately scaled up when appropriate (Research Program on Climate Change, Agriculture and Food Security, 2013). One of the biggest opportunities for the government is to improve agricultural extension services to help accelerate the traditional rate of learning and knowledge dissemination, and improve the distribution of improved seed and other technological innovations.

The government's plans for agriculture also overlap with other national priorities, like water conservation and improved catchment, and increased forest cover. Approaching CSA with a multiple-benefits perspective is helping the government align its departments and their activities, and is effectively aiming to mainstream the kind of landscape-level planning that CSA demands.

The SME Story for CSA

The differences between CSA and other clean technology sectors, and the types of activities that are involved in CSA, illustrate why the SME opportunities in this sector are significantly different from those in other clean technology sectors. The value chain approach—major equipment, installation and balance of systems, and O&M—is less clearly applicable than in the Indian solar or Kenyan bioenergy case studies.

Many CSA activities are rooted in behavior change, sustainable use of natural capital, and the intelligent application of knowledge and practice to natural systems. The activities that drive these CSA changes include clinical diagnostics of local threats and opportunities, education and awareness raising, farmer field demonstrations, and ultimately adoption of integrated, sustainable techniques.

Unlike the renewable energy, transport, and water and sanitation sectors, whose market sizes and commercial SME opportunities could be more easily articulated, CSA is often not a technocentric activity particularly on smallholder farms in developing countries. Many interventions require little or no new equipment. CSA plans also tend to be driven by government or donors, since the commercial returns of improved practice accrue to the farmer and community at large, rather than the trainer or extension agent, so the commercial opportunity space is more limited. Furthermore, individual farmers may be too small to serve profitably and most smallholder farmers are not ready to pay for education about new techniques.

However, in developed countries CSA technologies are emerging that are relevant. These technologies provide an indication of some of the opportunities that may emerge over time in developing countries. They include:

- Sensor-driven technologies, software, and robotics to drive precision agriculture, for instance, soil and plant sensors that monitor growing conditions and enable inputs to be tailored at small scales to increase productivity and reduce costs—SolChip is one example of an Israeli company developing wireless agricultural sensors.[22]

- Lighting technologies that can be tailored to the growing requirements of plants indoors, for instance, Valoya Oy is a Finland based company that is developing energy efficient light emitting diodes for more efficient indoor growing that improves product quality.[23]
- Greenhouse technologies, for instance, Israel based Drygair's combined heating and dehumidification systems for greenhouses.[24]
- Crop breeding technologies, for instance, hybrid potato breeding being developed by Netherlands-based Solynta.[25]

In addition, there are some interventions that already lend themselves to commercialization for SMEs in developing countries. Three such opportunities include:

- Drip irrigation systems;
- Improved storage facilities to reduce food waste; and
- Seedling plantations for agroforestry.

These areas and the opportunities they present for SMEs are described below.

Drip irrigation

Water stress is an issue in both India and Kenya. Drip irrigation is a technology that delivers an appropriate amount of water targeted at the roots of crops through a network of pipes and tubing, controlled by valves and delivered either under pressure or by gravity.

The micro-irrigation market is forecast to be worth $4.8 billion by 2018 and is growing at almost 20 percent per year (Transparency Market Research, 2013). Compared to other irrigation methods, drip irrigation can reduce total water consumption by reducing evaporation and minimizing deep drainage. In water stressed areas, drip irrigation may not reduce total water consumption, but can boost yields by delivering water more efficiently.

The technology varies in its sophistication, ranging from a bucket and hose with holes in it to a more precise system with anticlogging apparatus, backwash controller, and other innovations.

Drip irrigation systems can also be used to target fertilizer delivery. The combination of irrigation and fertilization is called fertigation. Such combined systems enable farmers to deliver fertilizer loads with precision and accuracy, which can reduce overall fertilizer use, minimize polluting runoff and harmful eutrophication (nutrient enrichment leading to excessive plant growth, decomposition, oxygen depletion, and fish death in surrounding water bodies), and reduce greenhouse gas emissions from inorganic fertilizer production and decomposition.

The technology helps reduce soil erosion, evenly distributes water resources, reduces weed growth, is less labor intensive, can reduce total water use or make water delivery more efficient, and is usually

BOX 6.3. Improving yields with drip irrigation

Godavari Polymers provides drip irrigation products for farmers to improve agricultural yields and reduce water consumption. It makes and sells drippers suitable for orchards, plantations, fruit crops, and broad spacing crops.

Godavari Polymers is a medium-sized enterprise in India specializing in polymer tubing, pipes, and sprinklers, and was recognized as the Best Performer of the Year—Manufacturing Sector at India's 2013 SME Excellence Awards for its rapid growth and high turnover. The company was established in 1991, and between 2009/10 and 2012, saw its turnover rise from about $14 million to over $25 million.

Its inline drip lines are made from polyethylene, which is resistant to ultraviolet rays, chemicals and fertilizer used in drip systems. Godavari uses sand as a primary filter, which is effective against organic impurities, algae and very fine suspended particles. It also offers fertilizer tanks to deliver water-soluble fertilizers like urea and potash to send equal portions to every plant root zone directly.

22 "News & Events." 2013. Sol Chip. http://www.sol-chip.com/

23 See "Professional LED Grow Lights." 2013. Valoya. http://www.valoya.com/

24 See DryGair, "The Company." http://www.drygair.com/

25 See "Solynta B.v." 2013. http://www.solynta.com/#home.

operated at low pressure, which can reduce energy costs and associated emissions from pumping.

Drip irrigation, however, can suffer from higher upfront capital costs, system clogging, and damage from rodents, and can interfere with harvesting.

SMEs in India and elsewhere are exploiting this agricultural opportunity and are expanding plastic and polymer manufacturing activities to capitalize on this growing market.

Food storage

Post-harvest food loss is an enormous global issue, with about one-third of all food produced lost because of storage issues, waste, or ineffective processing and logistics (FAO, 2011). Insufficient storage is a particular issue. It reduces incomes since predatory buyers can often buy crops at the farm gate for extremely low prices at harvest time because of an oversupply and an inability of farmers to store food and sell it when prices are higher. Inadequate storage also contributes to food insecurity, which exists when people do not have access to enough food in the right place at the right time that is accessibly priced and meets dietary needs and preferences.

India has a few large "safe and scientific" public food storage warehousing organizations, including the Food Corporation of India (FCI) and the Central Warehousing Corporation (CWC), as well as State Warehousing Corporations (SWC). The FCI is the largest food storage facility in India, with storage capacity of over 37 million tons (India Agronet, 2013; Food Corporation of India, 2014). Given the public role in large-scale food storage, the opportunity for SMEs lies more in the small and medium-scale storage market.

Traditional food storage devices include structures made of paddy straw, wheat straw, wood, bamboo, reeds, mud, bricks, and cow dung, which tend not to provide the security from pest infestation, rodents, and molds that more modern storage provides (India Institute of Technology, 2011). There is opportunity for SMEs to participate in this space.

Photo: World Bank

The variety of more modern storage facilities is considerable. SMEs can build mud or brick silos equipped with polythene films to prevent water intrusion, keeping grains fresher. Cylindrical rubberized structures supported by poles keep grains elevated to protect them from flooding and to reduce rodent problems. Grain is removed from such structures through capped holes in the bottom. Cover and plinth structures are silo-like structures that allow crates of protected grains to be stacked in conditions suitable for storage of between 6 and 12 months. They can be built in a matter of weeks and are an inexpensive and effective storage method. Modern silos, which can be made from either concrete or metal, are also effective storage options.

All of the above storage facilities are potential SME construction opportunities, and this activity is set to grow as India aims to reduce food waste through improved storage facilities.

BOX 6.4. Improving grain storage in India

G.T. Engineering Pvt. Ltd. produces, sells, and installs grain storage silo systems, chain, screw, and belt grain conveyors and belt and chain bucket elevators for food grain. A company with less than 100 employees, and based in Pune, Maharashtra, the company provides turnkey solutions for stable, waterproof and rated capacity silo systems

Seed plantations for agroforestry

Agroforestry is an important tool that can be included in the basket of CSA interventions. It creates integrated and sustainable land-use systems by combining agriculture and forestry, and capitalizes on the beneficial ecological dynamics of combining trees and shrubs with crop or livestock systems (USDA National Agroforestry Centre, 2013a). It draws on both traditional and modern land-use systems to increase the resilience of farmers to the impacts of climate change (Climate Smart Agriculture, 2014).

Trees can be used in different ways to produce benefits that are appropriate to local circumstances. They can protect and enhance natural capital, diversify income streams by producing wood for fuel or other productive uses, and can produce useful crops themselves such as fruit and nuts. The agricultural component of agroforestry can also help

BOX 6.5. SME opportunities in agroforestry

Maurice Kwadha is a Kenyan entrepreneur who recognizes the value of including trees in the agricultural landscape. He understands that the right kinds of trees in the right places can help to stabilize and replenish soil, retain moisture and provide shade, protect topsoil from water and wind erosion, and provide fresh food and also building material and fuel wood. Maurice has improved agricultural yields on his own farm while enhancing the resilience of his plot and diversifying his income streams.

Maurice has capitalized on his agroforestry success by starting a tree nursery. He has about 20,000 seedlings that he sells direct to farmers but also to the Kenyan government. His successful business demonstrates one of the SME opportunities afforded by agroforestry.

bridge the time it takes for trees to become mature enough to produce an income stream.

Alley cropping refers to the practice of growing trees simultaneously with agricultural crops. This allows high-value trees, like hardwoods or nut trees, to mature while the agricultural crops provide a steady annual income, allowing the landholder to diversify their income streams (USDA National Agroforestry Centre, 2013b).

Riparian forest buffers are stands of trees, bushes, and grasses planted and grown on riverbanks or the sides of streams. They stabilize the banks and prevent erosion, enhance biodiversity, and protect aquatic life, and act as a natural barrier to fertilizer runoff, reducing the pollution of waterways (USDA National Agroforestry Centre, 2013c).

Silvopasture combines trees and livestock in an integrated system that produces shade to help increase the productivity of livestock and forage while allowing trees to grow for other productive uses, such as fruits, nuts, timber, or fuelwood (USDA National Agroforestry Centre, 2013d).

Finally, windbreaks are made by planting trees in lines to protect crops, livestock, and soils from wind stresses. They buffer against storms, enhance soil water retention, reduce wind erosion, can reduce the visual and odor impacts of animals, and increase bee and insect pollination (USDA National Agroforestry Centre, 2013e).

Overall, agroforestry is an important opportunity that can help to increase yields, protect farmland, improve resilience to climate threats, enhance biodiversity, and diversify income streams. One SME opportunity lies in cultivating seedlings that can be sold for agroforestry purposes.

The World Agroforestry Centre has developed a toolkit and reference source, published in Kenya, to help SMEs get started in tree nurseries as an enterprise (World Agroforestry Centre, 2013). The toolkit outlines the elements of a business approach and how and why each element contributes to running a successful business. It also explains how to assess the market, price products, and determine which species will maximize profitability, as well as how to effectively market products and interact with competitors. Finally, it describes how tree nurseries can be a successful enterprise, and how it is only through commercialization of the activity that agroforestry practices can be sustained in the long term.

Conclusion

Agricultural systems are changing fast. The adoption of CSA in India and Kenya will improve the long-term sustainability of their farming systems and, if applied well, can improve yields and incomes, enhance food security and biodiversity, and reduce greenhouse gas emissions while increasing climate resilience.

Policy frameworks exist to promote CSA in both India and Kenya, although they have different focus areas. While many of the improvements required by CSA involve behavior change, modification of agricultural practice, and institutional reform, CSA also provides some opportunities for SMEs.

Three specific opportunities—drip irrigation, food storage and agroforestry—illustrate the potential for entrepreneurs to find and develop successful businesses that fit into the CSA framework. While this sector is different to other clean technology sectors, this case study shows that there are potential commercial opportunities for SMEs in all areas of clean technology.

Chapter 7

Actions to Support Clean Technology SMEs

Main Points

- This report has described the importance of SMEs to the growth of competitive clean technology industries. It has also illustrated that opportunities exist for developing country SMEs across clean technology industries and value chains. However, as illustrated (particularly in the case studies in Chapters 4, 5 and 6), the growth of these firms is also dependent on consistent support to overcome the challenges characteristic of clean technology firms.
- This chapter identifies five areas of action that should be considered by governments, development agencies, and other public and private actors to support clean technology SMEs in developing countries These areas are:
    - Entrepreneurship and business acceleration
    - Innovation finance
    - Market development
    - Technology development
    - Legal and regulatory framework

  Policy makers and other stakeholders can draw upon a broad tool-box of instruments in each of these five areas, to promote clean technology SMEs, listed in Appendix C and discussed in this chapter.
- Policy makers, in particular, must adopt and adapt these instruments to fit their country's circumstances. They should also seek to mitigate key risks, including failures to coordinate policy design and implementation, market distortions, and the effects of policy discontinuity.
- To illustrate considerations within specific national contexts, case studies of national programs targeting SMEs within green industry development are incorporated in the chapter. These include South Korea's Green Growth Strategy, India's National Solar Mission, Thailand's Energy Conservation Program, and Ethiopia's Climate Resilient Green Economy Strategy.

Photo: Curt Carnemark / World Bank.

Growing a Dynamic Clean Technology SME Sector Requires Sustained Commitment from Government and Other Stakeholders

This report has described the importance of SMEs to the growth of competitive clean technology industries. It has also illustrated that opportunities exist for developing country SMEs across clean technology industries and value chains. However, as illustrated in the case studies in Chapters 4, 5 and 6, investments in clean technology businesses often have higher upfront capital requirements, longer payback periods for investors and a heavier reliance on government policy than other technology sectors such as ICT. These issues can make clean technology markets more risky and difficult for SMEs to engage with. As such, and as part of a wider agenda to pursue "green growth," there is an important role for governments, development agencies, and other public and private actors to play in creating and supporting new markets for clean technology in developing countries.

BOX 7.1. National commitment: SMEs in South Korea's Green Growth Strategy

South Korea launched its Green Growth Strategy in 2009, with a primary focus on (i) the development of green technologies to provide new "growth engines;" (ii) the "greening" of traditional industries through greater energy and natural resource efficiency and waste management; and (iii) targeted support to emerging clean technology SMEs (Kamal-Chaoui et al., 2011). The key policy instruments being used, or planned to be used, in the Green Growth Strategy include:

- Credit guarantees for clean technology SMEs
- Public sector financing for clean technology R&D
- National public-private partnerships for education and training in key clean technology sectors
- Business skill training and competitions for clean technology SMEs
- Development of a cap-and-trade Emissions Trading Scheme (ETS)
- Carbon taxes for sectors not included in the ETS

The government implemented its first 5-year plan (2009-13) with public spending equal to 2 percent of GDP per year on about 600 projects with a total 5-year cost of Đ108.7 trillion (about $106 billion). During the first half of the 5-year Plan Đ14 trillion (about $13.7 billion) (1.3 percent of 2009 GDP) in credit guarantees were provided to clean technology SMEs by the state-backed Korea Credit Guarantee Fund (KODIT) and the Korea Technology Finance Corporation (KOTEC), providing for preferential fees.

Furthermore, the ceiling on guaranteed credit is set at Đ7 billion (about $6.8 million) for "green" businesses, compared to Đ3 billion (about $2.9 million) for nongreen loans. Government investment in green technologies rose from 16 percent to 20 percent of total government spending on R&D between 2010 and 2013, totaled Đ3.5 trillion (about $3.4 billion), making it the highest among all OECD countries as a proportion of GDP (Jones and Yoo, 2012). Under the strategy, the government's Small and Medium Business Administration (SMBA) facilitates collaborations between industry, universities, and research institutions and provides up to 75 percent financing to promising clean technology SMEs for technology development. In 2010, the SMBA awarded Đ56 billion (about $54 million) for 1,228 SME projects (Kamal-Chaoui et al., 2011).

Finally, the government is promoting the study of climate change at university level and has funded courses on renewable energy and clean technologies in the 36 regional polytechnic colleges, with the express aim of training a "green workforce" with links to local SMEs.

In nurturing innovative SMEs in particular, governments and other stakeholders can help businesses to capture value across the value chain and provide a basis for growth and innovation in national clean technology industries. Governments that have successfully promoted a dynamic clean technology SME sector have maintained a long term political and policy commitment to the participation of SMEs in these industries (World Bank, 2013i).

Five Areas of Support for Clean Technology SMEs

This section discusses five areas of support that should be considered by governments and other stakeholders to provide effective support to innovative clean technology SMEs in developing countries. These areas are:

- Entrepreneurship and business acceleration
- Innovation finance
- Market development
- Technology development
- Legal and regulatory framework

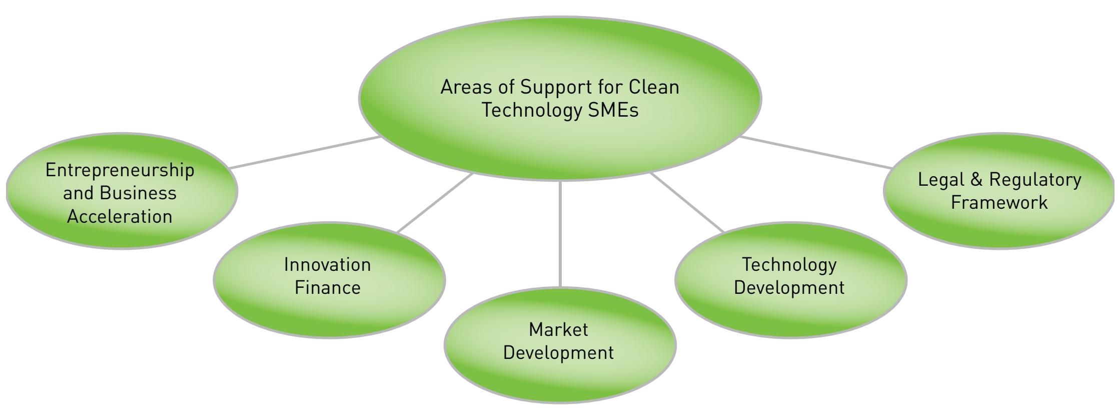
Policy makers and other stakeholders can draw upon a tool-box of instruments in each of these five areas to promote clean technology SMEs. These are listed in the tables in Appendix C, which provide a brief description, evaluation and applied country example. Here, "instruments" are referred to as the means by which the intent of a policy or program is accomplished. Indeed, policies and programs can include various instruments, all working towards the same goal. However in some cases, such as feed-in tariffs for renewable energy, the instrument is comprehensive enough to be considered a policy *per se*. While various studies refer to "enabling frameworks" as a specific subset of policy instruments (UNIDO, 2011) here this term is used in reference to all of the instruments, regulations and activities aimed at supporting clean technology SMEs.

Entrepreneurship and business acceleration

Entrepreneurship and business acceleration refers to actions designed to assist entrepreneurs in turning ideas into viable businesses, or to scale up an existing business or business line. This has traditionally taken the form of programs that provide direct training and capacity building to managers and owners of entrepreneurial businesses, ranging from general financial and managerial skills to targeted support for technical aspects of the business. These programs are frequently delivered by advisory services firms, business incubators or technical experts.

More recent programs seek to develop collaborations and networks that aim to assist clean technology SMEs to share knowledge and experience. These entrepreneurial networks, for the sake of collective and mutual innovation, can greatly reduce transaction costs for individual SMEs. By pooling resources and potentially sharing R&D and intellectual property rights (IPR), the costs of technology deployment and access to markets can be reduced. However, the success of such collaborations depends upon a high degree

FIGURE 7.1. Key Areas of Support for Clean Technology SMEs



of trust and openness, especially when faced with the risk of losing IPR to larger or better funded partners (Hultman et al., 2012). In some instances, these kinds of interventions have been designed to incubate and grow clean technology SMEs. For example, Climate Innovation Centers, supported by the World Bank's *info*Dev Climate Technology Program have been set up to provide in-country investment and advisory services to clean technology SMEs (see Box 7.2).

Collaborations between national governments, the private sector and the international community can also support the creation and sharing of technical knowledge, while building upon existing entrepreneurial cultures. They can innovate and deliver new models for financing and intellectual property sharing, and finance the demonstration of complex technologies that have strategic, transformative, value. Such international, public-private, collaborations are able to achieve these functions partly through education and capacity building for SMEs, but also through protections for intellectual property and the provision of economic resources and legal conditions required to enable commercial risk-taking.

Business clustering, that is, the sector-specific and/or spatial concentration of SMEs, has been studied in various geographical and sector-specific contexts, indicating their potential benefits. These include the facilitation of inter-firm cooperation, labor market pooling and technological learning and well as providing a focal point for targeted policy support (McCormick, 1999). Further, deliberate SME clustering can be of particular value to developing countries as they enable risk sharing between businesses and the pooling of limited capital and entrepreneurial skills within a defined space and infrastructure. However experiences from around the world show that clusters tend to benefit export-oriented markets, sectors with already-existing trade networks, and SMEs operating in relatively low-technology sectors such as textiles and non-electronics manufacturing. This suggests that efforts to stimulate clustering in the clean technology sector may be of limited benefit to SMEs supplying local and relatively high-technology markets.

Clean technology SMEs and the "greening of SMEs" can be also be supported by working in collaboration with large companies with long supply chains. An example is Mexico's Green Supply Chains program, a public-private partnership, which succeeded in achieving

BOX 7.2. *info*Dev's Climate Innovation Centers

*info*Dev is a global multi-donor program of the World Bank that supports growth oriented entrepreneurs in developing countries. *info*Dev's Climate Technology Program supports SMEs and emerging entrepreneurs that are developing innovative products and new business models in the climate technology sector. The CTP's flagship initiative is the development and implementation of country-level Climate Innovation Centers (CICs). The CICs are designed as locally owned and run institutions that provide a suite of services and venture financing that address the specific needs of local climate innovators and companies.

Currently, the program is establishing CICs in eight countries: Kenya, the Caribbean, Ethiopia, Ghana, India, Morocco, South Africa and Vietnam. The innovation centers in Kenya, the Caribbean, and Ethiopia are already fully operational while the others are in an advanced development stage. At the global level, the CTP is providing linkages between CICs by facilitating market entry, access to information and financing for the private sector, while also offering important tools for Policymakers to measure and improve domestic climate innovation activities.

Host country governments see the CICs as a key tool to support domestic private sector participation in growing climate technology opportunities to achieve economic growth and job creation. Climate technology SMEs and entrepreneurs look for the investment and advisory services that the CICs will provide for them to succeed. When asked about their interest in accessing CIC"s business advisory and financing services, the surveyed Indian and Kenyan clean technology SMEs were overwhelmingly enthusiastic (that is, 70 percent of Indian firms and 100 percent Kenyan firms).

This growing experience with CICs is now beginning to provide lessons about the effectiveness of targeted support to clean technology SMEs within a wide range of developing country contexts. Results are measured in terms of both economic impacts (for instance, growth and job creation of the supported SMEs), as well as environmental and social impacts (for instance, CO_2 mitigated, increased access to energy, or cleaner water).

improved productivity, competitiveness and natural resource efficiency for 146 SMEs working in partnership with 14 multinational companies (Van Hoof and Lyon, 2012).

Finally, public and private agencies can also conduct a facilitating and mediating role between entrepreneurs and their market clients. This can include awareness raising activities, information sharing and simple communication of ideas and opportunities of mutual interest to clean technology SMEs and their customers. Such activities constitute the intangible assets of human capacity necessary to make markets work, beyond the more easily measured financial barriers. Here, governments, other stakeholders, and SMEs can draw upon technical support and advice from a range of international collaborations and networks to promote clean technology and small business development (see Appendix C, Table C1).

Innovation finance

Innovation finance refers to instruments that aim to provide clean technology SMEs with several forms of early stage financing and risk capital, not available from traditional financing sources. This includes seed capital, venture capital, soft loans and loan guarantees (see Appendix C, Table C2). Here, governments and investors motivated by impact can also provide funding to bolster private sector lending to clean technology SMEs on preferential terms, that is, at lower interest rates and more flexible collateral and repayment conditions, or by providing loan guarantees. Such support addresses what is (beyond the absence of a high price for carbon emissions), in most countries, the most significant barrier to clean technology SMEs. This was confirmed in the surveys in India and Kenya (see Chapters 4 and 5) where access to finance was identified as the most significant barrier to SMEs operating in clean technology sectors, especially in Kenya where 70 percent of bioenergy firms identified it as the primary barrier, compared to 46 percent of solar energy firms in India.

To some extent, the high cost of capital and business financing for clean technology SMEs often reflects a lack of awareness on behalf of local banks about clean technology opportunities, which translates into higher financial risk assessments. However the decision to invest in clean technology SMEs, even for those seeking finance for proven technologies in existing markets, also presents opportunity costs for local banks where high and reliable rates of return can be secured from lending to high-turnover businesses, for example those trading in high-volume, perishable goods (Haselip et al., 2014). There can also be a strong cognitive bias on behalf of potential lenders in favor of traditional business activities, as they are unused to viewing the world through a clean technology "lens" and hence perceive more problems than solutions. While "impact investment," or investments made against "triple-bottom-line" calculations are more likely to tolerate a higher rate of strictly financial risk in the face of clearer environmental and social benefits, the aim of instruments to push demand for clean technology products and services should be to attract investors that are not necessarily seeking these non-financial rewards. In this sense, instruments should aim to normalize the market whereby investment in clean technology becomes profitable and hence "rational."

Other factors, including the relatively high transaction costs of investing in SMEs and the longer supply chains inherent to the market structure of many clean technology businesses, also serve to increase the financial risk of investing in clean technology SMEs. Given this reality in many developing countries, government-backed support for concessional and/or flexible loans creates the risk that these businesses become dependent upon non-market financing. In order to mitigate this risk, and enable a longer-term transition to market-based financing, soft loans and credit guarantees must be issued through commercial banks that set their own financial and technical criteria. This "double assessment" approach is particularly relevant for SME startups or development projects that involve a significant technological element, thus increasing both borrower and lender confidence. Equity financing is another supply-side option for clean technology SMEs in the early stages of the innovation cycle, however even in OECD economies equity financing is used by less than 2 percent of SMEs, with the vast majority dependent upon internal or debt finance (MENA-OECD, 2011).

Innovation finance can also operate on the demand side. Here, the most important instrument to promote growth in clean technology markets is technology-specific consumer credit. Such facilities can greatly overcome the financial barriers surrounding high capital cost goods, such as off-grid renewable energy technologies

(RETs). For example, high demand for solar water heaters (SWHs) in South Africa, Tunisia and Mauritius has largely been due to the availability of low-cost commercial loans, offered specifically for SWHs (Ölz, 2011). These technology-specific credit markets have enabled, and were enabled by, greater awareness and acceptance for SWHs, lowering risk premiums. In the case of small-scale and off-grid clean technologies, SMEs tend to benefit most as the market for retail, installation and maintenance favors smaller, local, businesses.

Market development

A range of instruments aim to increase demand for the products of local SMEs and facilitate the overall growth of the clean technology market. The main purpose of demand-side instruments is to reduce commercial uncertainties for businesses supplying clean technologies, thus reducing investment risk (OECD, 2012). Support for consumer financing, as discussed earlier, is an important means to stimulate the growth of clean technology markets at the household level. However there is also plenty that governments can do to stimulate industrial demand for clean technology.

In the area of renewable energy, the most well-known instrument to strengthen market demand for grid-connected technologies in developed countries has been feed-in tariffs, which support approximately 75 percent of global installed solar PV capacity and 45 percent of wind power (Deutsche Bank Group, 2010). While FITs have been instrumental in driving demand and cost reductions in RETs in developed countries, their presence in developing countries is relatively recent and so their impact is yet to become clear. However, given that FITs operate as a cross subsidy, where the cost of tariff-supported RETs is divided among all grid-connected consumers, this particular instrument becomes less economically viable and relevant in lower-income countries where levels of energy access remain low.

Renewable Energy Portfolio Standards or Obligations and Renewable energy certificates (RECs) are also widely used to develop renewable energy markets. These are government-imposed mandatory targets for utilities to generate X percent of their power from RETs, that normally result in the creation of certificates which can be "surrendered" or traded, providing a market-based subsidy. While RECs are a market mechanism, their prices are largely influenced by the regulatory framework that creates them. Therefore the penalties for non-compliance must be significant, and floor prices should be set high enough to ensure energy companies are incentivized to invest in clean technologies.

Large organizations, whether they are private corporations or government departments, can have a significant influence in driving demand for clean technology by mandating sustainable procurement policies. However the exact criteria used will vary significantly between organizations, thus consumption that is radically more sustainable than "business as usual" does not always occur and hence close attention must be paid to the detail of procurement policies.

Similarly, manufacturer standards, product labeling and product testing and certification are potentially powerful means to drive demand for clean technologies and raise consumer awareness. However such instruments are mostly limited to consumer goods such as household appliances which are of marginal significance to SMEs in developing countries since such goods are more likely to be imported than manufactured locally. Nonetheless, government-imposed standards, for example for energy efficiency in buildings, are an important means to drive demand for clean technologies that are likely to be supplied or installed by SMEs. India's National Solar Mission (detailed in Box 7.3) is a good example of a national strategy to help develop a specific clean technology market, drawing upon a range of complementary instruments.

Photo: Danilo Pinzon / World Bank

BOX 7.3. SMEs in India's National Solar Mission

India's National Solar Mission was launched in 2010 and aims to accelerate the use of solar PV and solar thermal technologies, with a target of 20,000 MW of grid-connected and 2,000 MW off-grid solar energy capacity by 2022 (PWC, 2014). The national solar energy strategy is one of eight missions launched under the country's national action plan on climate change, and is divided into three phases (Government of India, 2010). Various instruments are being used at the state level to incentivize investment in grid-connected solar energy and local manufacturing capacity. These include:

- Renewable Purchase Obligations
- Renewable Energy Certificates (RECs)
- Feed-in tariffs
- 50 percent of all capacity is subject to a "domestic content requirement" of solar cells and modules
- Incubation of startup solar SMEs
- Concession loans to solar SMEs

India's 2003 Electricity Act is credited with enabling an increase in private sector investment in renewable energy capacity, which is driving the solar market. However, policy and regulatory incentives are at an early stage of development and have suffered some setbacks, including the weak economic impact of the RECs market, launched in 2011 (Climate Policy Initiative, 2012).

Under the Solar Mission, SMEs are benefitting in a similar way to how they did under the ICT revolution, that is, by operating in the slipstream of large corporations who are driving the market, and by innovating technological solutions and local manufacturing skills and capacity. Indeed, SMEs mostly occupy the manufacturing level of the solar market supply chain in India, supplying mostly electronics equipment such as inverters, batteries, micro-controllers, chargers, cable connectors, and meters. Here, the solar strategy benefits from the strong power electronics base, already present in India. The Indian Renewable Energy Development Agency (IREDA) provides concessional loans for SMEs partaking in RET projects and incubation of solar SMEs is conducted by centers such as the Centre for Innovation, Incubation and Entrepreneurship (CIIE) in Gujarat (Ministry of New and Renewable Energy 2014).

Finally, there are numerous "soft" interventions that public agencies, NGOs and charities can pursue to promote clean technologies. These include education, which can operate at various levels from primary to advanced, to either raise awareness about clean technology or build specific capacities and campaigns which can take many forms and be official (that is, government-led), commercial, individual or community-based and broad or specific in focus. Authorities or well-known organizations can also promote a spirit of competition between countries, businesses, organizations or municipalities based on the production or consumption of clean technology, in the form of public rankings. The strengths and weaknesses of these instruments are presented in Appendix C, Table C3.

Technology development

Technology development instruments aim to assist SMEs with the technical aspects of developing an innovative product. These can include R&D tax credits, research grants, publicly funded competitive research collaborations, competitions, public investment in R&D, public or private agreements on technology cooperation, demonstration projects and applied research networks. These instruments are briefly assessed in Appendix C, Table C4.

Perhaps unsurprisingly, 43 percent of the Kenyan firms surveyed in this report (see Chapter 5) stated that governments could provide more funding for R&D, with 31 percent identifying loan guarantees or discounted financing as most useful, followed by 19 percent in favor of direct subsidies. Similarly, in India direct subsidies were identified as being the most popular form of government support by clean technology firms (32 percent).

While instruments to provide public support for R&D can be a powerful catalyst to the development of clean technologies and local SME capacities, they also carry structural risks that policy makers should consider and anticipate. Above all, government funding for R&D may result in an inefficient allocation of resources as a non-market means to pick technology and business model winners, and/or result in over-subsidization that leaves technologies far from the market. Policy makers also need to consider the risks of political capture and rent seeking surrounding the use of subsidies, as well as opportunity costs where the potential benefits of supporting other markets and technologies may be significant. Therefore, when taking the decision to finance R&D, policy makers must ensure that this does not occur at the expense of private sector innovation funding, and that the commercialization phase of clean technology innovation is determined by market forces (Hultman et al., 2012; UNDESA, 2011).

Another significant area of technology development concerns Intellectual Property Rights (IPR). This is a controversial aspect of the debate surrounding climate technology development and transfer, given the perceived conflict between the provision of legal patent protection (and hence profits) to incentivize private sector investment in R&D, and the need for developing countries to purchase clean/low-carbon technologies at affordable prices. In recognition of the strategic importance of patenting in the "knowledge economy," many developing countries have implemented patent policies, often with technical support and funding from international organization such as the World Intellectual Property Organization (WIPO). Rwanda, for example, has a comprehensive IP policy as a means to support scientific and technological capacity and technology transfer (European Patent Office/UNEP, 2013).

Further issues relate to the trade-off between effective enforcement mechanisms and the need to provide geographically-appropriate technologies. Here, some attention has been given to the potential role of Open and Compulsory License Agreements for climate technologies, that is, legal permission to use software or manufacture technology hardware without the consent of the patent owner, as has been used for drugs under the WTO's Trade-Related Aspects of Intellectual Property Rights (TRIPS) agreement. However it is unlikely that a global agreement will be reached on whether climate change should be rightly considered a public health issue, thus covering low-carbon technologies under the TRIPS provision. This is partly because of the greater number of patents required for specific climate technologies, as compared, for example, to drugs for HIV/AIDS. Growing competition from emerging economies also makes compulsory licensing less likely, and there is wide agreement among private sector actors that it would dampen incentives to invest in clean technology innovation (Ebinger and Avasarala, 2009).

An important means of overcoming the aforementioned barrier is for governments, multilateral organizations and the private sector—working together or separately—to launch competitions, backed with monetary prizes.[26] Competitions, if well-focused, can drive innovation especially for bottom-of-the-pyramid and/or technologies for problems that have been neglected by the market in developing countries (Dutz and Sharma, 2012). Such competitions would attract mostly innovative SMEs, driving local interest, creativity and competitive advantage.

Legal and regulatory framework

The legal and regulatory framework is the set of laws and related regulations that aims to strengthen the overall enabling environment for clean technology SMEs, adding weight to the instruments discussed in the preceding sections. Here, the main instruments are: sector-specific tax incentives, emission reduction credits, taxation on pollution or natural resource use, import tax reductions or waivers and incentives to attract skilled labor. These can be broadly divided into "carrot" and "stick" instruments, creating incentives or obligations that address both the supply and demand side of clean technology markets (see Appendix C, Table C5).

In terms of financial incentives for clean technology SMEs, governments can introduce sector-specific business income tax breaks and import tax reductions or waivers. Such tax-related incentives can result in efficiency and productivity benefits, driving innovation and profitability (KPMG 2013). In general, the main benefit of legal and regulatory instruments to support the supply-side is that they offer non-prescriptive support, that is, they tend to be generic and not technology-specific, encouraging early-stage business innovation and competition. However strict criteria and oversight is required in order to avoid non-eligible businesses claiming tax benefits, especially with regard to import tax relief. There are also risks surrounding the use and effectiveness of tax credits in countries with widespread tax evasion.

On the demand side, governments can establish clear economic signals that "polluters pay," in order to stimulate clean technology use and innovation (KPMG, 2013). To this end, Governments can impose taxation, charges or

26 Competitions can also be viewed as a mechanism to drive demand for clean technologies, however this discussion is about competitions used as a means to achieve a pre-defined target or objective, hence pushing investment and innovation in a particular direction.

BOX 7.4. SMEs in Thailand's Energy Conservation Program

Thailand first made serious efforts to promote energy efficiency with its Energy Conservation Promotion Act of 1992, which has since been revised and expanded. The centerpiece of this policy is the Energy Conservation Promotion (ECON) Fund, which is financed by a $0.001 per liter charge on petroleum, raising about $50 million per year, which is then invested into support for energy efficiency projects (Grüning et al., 2012). By 2012 the program was estimated to have resulted in a reduction in peak electricity demand of 2,600 MW and a cumulative saving of 15,700 GWh of energy (Polycarp et al., 2013). The main policy elements of Thailand's drive to increase energy efficiency include:

- Renewable Purchase Obligations
- Taxation on fossil fuel consumption, demarcated for investment in energy conservation (ECON)
- Active involvement of multilateral and donor organizations for financing and technical assistance
- Revolving fund for concessional loans

The ECON fund is used to support various agencies implementing energy conservation projects, as well as renewable energy, R&D, training, and public awareness campaigns, through grants, subsidies, and tax incentives and two dedicated funds for energy efficiency: the Revolving Fund and Energy Services Company (ESCO) fund. The revolving and ESCO funds provide credit to local banks that issue low-interest loans to project developers. The country's support for energy efficiency has driven demand for efficient transport, lighting, air conditioning, and solar energy technologies, as well as construction and insulation materials. Large, mostly foreign, corporations have taken the largest share of the market in energy efficient technologies, which are mostly imported to Thailand. However, SMEs have obtained some market share through the retail, installation, and maintenance of energy efficient equipment, such as air conditioners, solar thermal systems, and low-energy lighting systems.

Another way in which SMEs have accessed the energy efficiency market is through the ESCO model, supported by the ECON fund. Indeed most ESCOs are SMEs and suffer from the same financial barriers as SMEs in other sectors, where banks have been less familiar with the ESCO model and hence less willing to lend to them, which in turn has limited their participation in the revolving fund (Polycarp et al., 2013).

levies on pollution, waste production and/or the unsustainable consumption of natural resources. As an alternative to taxation, governments can utilize market-based mechanisms such as the trade in emissions permits or credits, whereby economic entities are subject to an emissions cap (absolute limit) which obliges actors to reduce emissions or waste, instead of simply punishing them. However the cap on emissions must be tight and become more stringent over time, in order to set permit prices at a meaningful level. In support of market mechanisms, taxation can be deployed as a "baseline instrument" to send the economic signal, especially to major industrial emitters, that investment in clean technology is an act of self-interest (OECD, 2012).

Here, the effectiveness of pollution taxation depends upon strong and sustained political support so as to give clear signals that delayed investment in clean technology will result in higher costs. Although emissions trading and taxation is mostly targeted at large corporate players, SMEs stand to benefit directly from these policies as they strengthen demand for technical solutions to reduce emissions and waste, much of which will come from innovation-led SMEs and from those contracted to install, operate and maintain clean technology solutions. The case study on Thailand's Energy Conservation Program (see Box 7.4) refers to a mix of legal and regulatory instruments, as well as an innovative financing mechanism, to drive the supply and demand for energy efficient technologies.

In addition to the presence of economic incentives, the growth of clean technology SMEs also depends upon a country's "absorptive capacity" which is the result of creative talent and a skilled workforce operating within a favorable business environment to enable experimentation and learning. Here, one instrument to attract relevant skills and talents is to offer income tax benefits and/or subsidies to targeted individuals, the so-called "sticky cities" policy. This can be a low-cost, low-risk, option for governments and is of particular value to less developed countries that typically suffer a "brain drain" to richer counties. However reversing this trend is a challenge and success depends upon concerted efforts to attract a critical mass of individuals, working in a specific sector.

Country Context

There is limited empirical knowledge regarding the relationship between specific developing country contexts and the most effective instruments to promote clean technology industries. However, there are a number of national, economy-wide, conditions necessary to support clean technology industries, whether investors are domestic or foreign. These include a stable macroeconomic environment, meaning rational interest rates, tight control over inflation and competitive exchange rates. More generally, countries should have undergone, or be in pursuit of, reforms to simplify and minimize the cost of business registration and formalization, including decentralized administration, strong rule of law, contract enforcement, pro-business bankruptcy and re-entry rules. While these may appear obvious prerequisites that stand to benefit all industries, there can be profound contradictions between a government's sector-specific policies and the wider economic and business framework, thus hindering clean technology industries.

When designing instruments to support clean technology industries, governments, in particular, should take into account their country's administration and innovation capacities, in order to pursue realistic goals and strategies (UNDESA, 2011). This applies to education policies through to IPR regimes, though the need to take into account national development circumstances is perhaps most important when thinking about clean technology transfer. For countries with weaker capacities, it makes more sense to focus on attracting foreign direct investment (FDI) and in creating a role in global value chains, where joint ventures with foreign firms are the best options for securing technology transfer, in addition to supporting local research capacities.

An example of this is Egypt's Kuraymat Integrated Solar Combined Cycle power plant, a grid-connected project including 20MW of concentrated solar capacity, which became operational in June 2011. Sixty percent of the value for the Kuraymat plant was captured by local SMEs through the supply of civil works, mounting structure, tubes, electrical cables, grid connection, engineering, and procurement and construction responsibility. Many local SMEs obtained knowledge and skills regarding the design, construction and maintenance of the solar plant, in the process of working with foreign firms (MEDREC, 2013).

There is also a range of social and cultural barriers to the update of clean technologies that may inhibit the growth of clean technology industries. These can include limited acceptance or trust in the suitability or reliability of clean technologies, as well as consumer resistance on the basis of aesthetic criteria, for example in the uptake of roof-top rain water harvesting. Resistance at the community level has also been experienced, for example in efforts to encourage collectivized food storage in flood-prone areas. Tradition, social esteem, pride and religious beliefs may also be a source of resistance to the uptake of climate technologies. However there are various options to address these barriers, including campaigns to disseminate information, educate and raise awareness as well as public-private partnerships and targeted assistance to promote early adopters and technology front runners (Boldt et al., 2012).

Policy Interaction and Risk

In addition to providing active, positive, support for clean technology markets via the menu of instruments detailed in tables in Appendix C, governments and regulators also need to ensure that they remove or minimize any "negative incentives," that is, fiscal instruments, subsidies or regulations that favor conventional energy and other "dirty tech" markets. Action to remove or reform such policies, thus reducing policy conflicts, is another key aspect of an enabling framework for clean technology SMEs.

Negative incentives for clean technology SMEs in developing countries are likely to result from red tape and import taxation, as well as more sector-specific regulations that restrict market access, such as monopoly status awarded to State utilities to generate electricity or operate water treatment plants. For example, despite low levels of rural electrification, the Tanzanian utility TANESCO maintained control over all grid and mini-grid power generation up until the creation of the Rural Energy Agency (REA) in 2008. Since then the REA has supported small-scale independent power producers, thus opening up investment in small scale hydro power and mini-grid technologies to supply villages and rural areas (Uisso, 2011).

Another source of policy conflict that undermines clean technology SMEs are subsidies issued to fossil fuels, which remain widespread in both developed and developing countries (Whitley, 2013).

BOX 7.5. Ethiopia's Climate Resilient Green Economy Strategy (CRGE)

The Ethiopian government launched its Climate Resilient Green Economy Strategy (CRGE) in 2011 to support the 5-year Growth and Transformation Plan (GTP), which aims for the country to obtain middle-income status by 2025, via carbon-neutral growth. This is an ambitious target, especially given the country's high GDP growth rates, which averaged 10 percent between 2004 and 2013. The CRGE stands out as being a model strategy in bringing green economy and climate resilient objectives to the forefront of national economic planning. Indeed, on paper, it is difficult to fault the CRGE, which, unlike green strategies in many other countries, benefits from high-level support and oversight. The CRGE Ministerial Steering Committee operates within the Prime Minister's Office, and works in partnership with the Ministry of Finance and Economic Development and the Environmental Protection Agency.

In a similar way to the Korean Green Growth Strategy, the CRGE is made up of a portfolio of specific projects, across numerous sectors. These include the fast-tracking of support to develop the country's hydro power resources, the scaling up of fuel-efficient cooking stoves in rural areas, efficiency improvements to the livestock value chain, and financing for Reducing Emissions from Deforestation and Forest Degradation (REDD) projects (Federal Democratic Republic of Ethiopia, 2012). Although some policy instruments have been legislated, including a FIT to support investment in grid-connected renewable energy, most of the strategy will be delivered through direct investment and spending from a central fund, managed by the Ministry of Finance and Economic Development. This fund, known as the CRGE Facility, aims to mobilize $200 billion from national and international public and private sources over a 20-year period and has already received international donor support, including $24 million from the U.K. government (GGGI, 2013). In terms of how these funds are spent, the government has established the Sectoral Reduction Mechanism Framework, which purports to outline the precise mechanisms of implementation, though it makes scant reference to clean technology innovation or the role of SMEs. Indeed this highly centralized approach risks resulting in an inefficient distribution of resources if private sector actors and investors are not systematically drawn into decision-making processes.

Another risk is weak implementation or enforcement of the government's stated policies. It remains to be seen if the CRGE's clear national vision and planning will be translated into lasting support for the private sector that is necessary to develop green industries in Ethiopia.

Governments often justify these subsidies on the basis of welfare, for example for kerosene which remains an important fuel for domestic lighting in rural, off-grid, Africa. However, technical progress and cost reductions with solar lighting technology mean that subsidies for kerosene are no longer justified, and in fact governments would be advised to tax unsustainable fuels, further driving the market for clean technology alternatives.

Clean technology SMEs and investors that depend upon government policies and regulations for the size and strength of their markets need to be aware of the risk of policy discontinuity. There are two types of such policy risks: prospective and retroactive risk. Prospective policy risk refers to the overall level of instability or uncertainly regarding a country's enabling framework, upon which clean technology SMEs may depend. In other words this is the risk that governments will make frequent or irregular and unpredictable changes in policies that may have a negative impact on project planning, thus pushing up the cost of borrowing or the rate of return demanded by investors. Retroactive policy risk refers to changes in policy or regulations that affect existing projects, especially when they have an impact on business income. Indeed, retroactive changes to policies that financially support clean technology investments has become a main barrier to scaling up private investment in the renewable energy sector (Micale et al., 2013).

In the area of renewable energies, the most well-known risk relates to changes in the value of feed-in tariffs where, for example, the Spanish government issued a decree limiting the rate of return on RET investments to 7.5 percent, effectively cutting the value of tariff support by up to 25 percent for both existing and future projects (PV Tech, 2014). Such retroactive changes in key financial instruments are what businesses and investors fear most as it can result in a drop in forecast revenues, increase borrowing costs and diminish the confidence of investors, undermining market growth prospects. There are various circumstances under which such changes tend to occur, though the most are related to changes in the political ideology of presiding governments and economic crises.

While policy change is not always and necessarily bad for business (indeed sometimes it is welcomed), changes especially to instruments that provide financial support to investments must be developed in consultation with the affected businesses and investors. Ideally change should be implemented gradually, after plenty of warning. Indeed, sudden and unexpected changes in policy are likely to cause most damage, especially when foreign companies and investors are involved.

Finally, it is important to bear in mind the challenges surrounding the implementation, enforcement and regulation of any given instrument. In many developing countries this issue presents the greatest risk, where even well designed legal frameworks and financial mechanisms can fall victim to poor implementation or compliance. Regulatory policies, such as import tariff waivers designed to support clean technology sectors, can create incentives for corruption as does the demarcation of government funds to support nascent industries. Indeed, 26 percent of the solar energy firms surveyed in India (see Chapter 4) identified corruption as a major barrier facing the development of their business, with 22 percent pointing to unfavorable customs and trade regulations. In order to reduce the risk of rendering supportive instruments obsolete because of poor enforcement, governments and other stakeholders must sustain capacity building programs, combined with reforms that allow for greater transparency, reporting and auditing processes throughout public administration. Box 7.5 discusses some of these issues, with regard to Ethiopia's Climate Resilient Green Economy Strategy.

In the least developed countries and those with major resource constraints, governments and other stakeholders are advised to identify clean technology "sweet spots" in order to maximize the co-benefits of economic growth and climate resilient development or greater energy access. This is of particular importance in countries whose greenhouse gas emissions are of global insignificance, such as in most Sub-Saharan African countries, where there is a far greater need for economic development than climate change mitigation. In such countries, instruments that support clean technology sectors should be integrated into national development strategies,

BOX 7.6 Climate Smart Agriculture—a potential "sweet spot" industry offering environmental and social co-benefits?

As discussed in the previous chapter, CSA is more a product of behavior change than hard technological change; hence, policy support should be geared more towards shifting farming away from unsustainable practices. However the widespread uptake of CSA policies by governments provides some opportunities for SMEs (including small holder farmers) through demand for drip irrigation, food storage and similar technologies. In order to design a policy framework to stimulate CSA, there is wide agreement on the fundamental need for effective coordination between national agricultural development plans, food security and climate change (FAO, 2010). Since these are often the domain of different Ministries, such coordination is a challenge.

In terms of specific instruments to support CSA, the FAO identifies three key mechanisms: reformed credit, insurance and payments for environmental services, all of which should be designed to incentivize farmers to adopt CSA practices. First of all, commercial credit and insurance sold to farmers needs to be reformed in order to incentivize the use of crop residues and restoration projects, which usually involve withdrawing land from short-term production, in order to obtain greater longer-term productivities from increased natural fertility. Traditional credit and insurance products do not encourage such practices and view these ecological investments as negative financial trade-offs. Governments are also able to legislate payments for environmental services, in support of the transition to CSA. Payment for environmental services, such as the mitigation of climate change, has been successful in the forestry sector and is a service that smallholder farmers can easily provide, as a means to compensate for the short-term productivity losses that often result from CSA practices.

Many countries have already proposed the use of these instruments through national strategy or planning processes, such as Poverty Reduction Strategy Papers (PRSPs), National Action Plans for Adaptation (NAPAs), Nationally Appropriate Mitigation Actions (NAMAs) or Technology Needs Assessments (TNAs) for climate change. In addition to highlighting the ecological benefits of CSA, governments and other stakeholders could explore the potential benefit of CSA as a driving force for local SMEs supplying clean technologies, adding, where necessary, political support to the CSA agenda.

targeting the most attractive value chains, as discussed in Chapter 3.

Conclusions

This chapter has discussed the broad tool-box of instruments to promote clean technology SMEs that public policy makers, development agencies, and other public and private actors can adopt and adapt to fit their country's circumstances. These instruments have been categorized into five areas: entrepreneurship and business acceleration, innovation finance, market development, technology development and the legal and regulatory framework.

- **Entrepreneurship and business acceleration:** There is a range of programs for businesses, as well as international collaborations and networks, which countries and businesses can draw upon to help strengthen SME entrepreneurship and business acceleration in clean technology sectors. Here, countries can pursue programs offering direct technical assistance and the linking of foreign investors with local clean technology SMEs for technology development and/or production capacities. More hands-on and in-country business incubation is also expanding, such as infoDev's Climate Innovation Centers.
- **Innovation finance:** There are various instruments available to support early stage financing and risk capital for clean technology SMEs, to complement traditional financing sources. These include providing soft loans and loan guarantees and stimulating seed and venture capital investment. On the demand side, there is a significant opportunity to establish technology-specific consumer credit facilities, which have proven particularly useful for technologies that require higher up-front investments such as renewable energy systems.
- **Market development:** A range of instruments aim to increase demand for the products and services of local SMEs and facilitate the overall growth of the clean technology market. For renewable energy these include portfolio standards, renewable energy certificates and feed-in tariffs. Clean technology markets can also receive a rapid boost through strict sustainable procurement policies, manufacturer standards, product labeling and product testing and certification, as well as indirect and/or "soft" interventions such as education, campaigns and performance rankings.
- **Technology development:** Instruments designed to stimulate technology development include R&D tax credits, research grants, publicly funded competitive research collaborations, competitions, public investment in R&D, public or private agreements on technology cooperation, demonstration projects and applied research networks.
- **Legal and regulatory framework:** The overall enabling framework for clean technology SMEs can be strengthened by implementing a number of legal and regulatory policies, including sector-specific tax incentives, cap-and-trade emission schemes, emission reduction credits, taxation on pollution or natural resource use, import tax reductions or waivers and incentives to attract skilled labor. These can be designed to create business incentives and/or obligations that address both the supply and demand side of clean technology markets.

This chapter has also discussed the importance of designing and implementing these instruments in parallel, as part of a broader, national strategy to support clean technology industries. Policy makers and other stakeholders are advised to take into account their national circumstances and focus attention on developing policy interventions on "fertile ground," as opposed to supporting technologies and sectors that do not have the support of already-existing human and natural resource capacities.

In order to achieve complementarities and policy coherence, policy makers and other stakeholders are also advised to survey the portfolio of existing instruments and conduct a harmonization analysis, that is, to understand if and how other instruments and national economic circumstances stand to conflict with, or undermine, planned interventions to support clean technology SMEs. The case studies highlighted in this chapter illustrate how effective policies have been used to promote a dynamic SME sector within specific green industries.

Photo: Boris Balabanov / World Bank.

Appendix A. Market Sizing Methodology

The market sizing methodology has five main steps (further detail available upon request):

1. Regional clusters were defined based on a variety of indicators that allowed for modeling of regional opportunities amongst similar countries. This allowed country-level data gaps to be filled by extrapolation. The clusters group similar countries within regions, with India and China treated as stand-alone, both because of their relative uniqueness, size, and better data availability.
2. A short list of clean technology sectors was created and the overall market value for each sector for each region was estimated using a variety of data sources, including: investment projections, installed capacity projections, and national plans. Country data gaps within regions were filled by extrapolation using GDP as the main scaling factor.
3. The value chains for each sector were mapped and the proportion of value in each segment estimated (for instance, 40 percent of the value is in major equipment; 10 percent in engineering, procurement and construction; and 50 percent in operations and maintenance). This was combined with the regional estimates of sector market value to estimate the addressable market in each segment.
4. The share of each value chain segment that could be captured by local SMEs was estimated. A rating of Low, Small, Medium, or High was assigned to each value chain segment for each sector with a corresponding fixed percentage for each rating in order to estimate the value that could be captured by local SMEs. The ratings were based on the technical complexity and market structure of the segment and experience in the United Kingdom of working with SMEs in clean technology across the value chain.
5. All of the estimates were sense checked against existing global estimates and the findings from the case studies. In the analysis of opportunities the subregions were reaggregated to more conventional regions for the purposes of presenting the findings.

TABLE A1. Market sizing methodology

Classify countries into regional clusters (11 regions, 2 country stand-alones)			
Geography	Population and GDP	Innovation capacity	Ease of doing business

↓

Develop regional market projections (15 technology areas)		
Investment projection per region	Installed capacity projections per region	Regional projections extrapolated from national plans

↓

Map the value chain (lifetime)		
Major equipment	Engineering, procurement, and construction	Operation and maintenance

↓

Estimate the opportunity for SMEs (average)		
Technical complexity of value chain segment	Localization of activity	Authors' analysis

↓

Triangulate findings

Appendix B. Value Chain Breakdowns

TABLE B1. Renewables value chains

Technology	Major Equipment	EPC	O&M
Onshore wind	57% **Turbine** • Tower 28% • Blades 22% • Gearbox 11% • Power converter 5% • Transformer 4% • Generator 3% • Other equipment 27%	22% **Civil works** 44% • Foundation • Site access & preparation • Building construction **Balance of system** 31% • Control systems • Substations • Grid interconnection **Other costs** 25% • Project consultancy • Planning / feasibility / permitting costs	21% • Insurance • Administration • Fixed grid access fees • Routine component and equipment maintenance • Replacement parts & materials • Labor costs
Solar thermal	45% **Solar collector** • Evacuated tubes • Flat plates	37% **Civil works** • Site preparation **Balance of system** • Collector mounting components • Storage vessel • Plumbing **Other costs** • Project development, EPC, financing costs, allowances	19% • Routine inspection • Maintenance of absorption and adsorption chillers
Solar PV >1 MW	54% **PV module**	36% **Civil works** 57% • Structural installation • Site preparation **Balance of system** 29% • Solar racks • Inverter • Transformer • Wiring • Battery or storage system **Other costs** 14% • System design, permit fees, management, up-front financing costs	10% **Routine inspection** **Preventative maintenance** • Panel cleaning • Vegetation management • Upkeep of power and monitoring systems **Corrective maintenance** • Critical repair • Warranty enforcement

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TABLE B1. Renewables value chains *(continued)*

Technology	Major Equipment	EPC	O&M
Solar PV <1 MW	45% **PV module**	46% **Civil works** 57% • Structural installation • Site preparation **Balance of system** 29% • Solar racks • Inverter • Transformer • Wiring • Battery or storage system **Other costs** 14% • System design, permit fees, management, up-front financing costs	9% **Routine inspection** **Preventative maintenance** • Panel cleaning • Vegetation management • Upkeep of power and monitoring systems **Corrective maintenance** • Critical repair • Warranty enforcement
Solar CSP	36% **Solar field** 80% • Mirrors • Receivers • Steel construction **Thermal storage system** 20% • Salt • Storage tanks • Insulation materials • Foundations • Heat exchangers • Pumps	55% **Civil works** 35% • Structural installation • Site preparation **Balance of system** 30% • Balance of plant • Power block • Heat transfer fluid system • Grid interconnection • Electronics and controls **Other costs** 35% • Project development, EPC, financing costs, allowances	9% **Routine inspection** **Preventative maintenance** • Mirror washing • Vegetation management • Upkeep of power and monitoring systems **Corrective maintenance** • Mirror & receiver replacement • Warranty enforcement • Plant insurance
Small hydro	23% **Electro-mechanical equipment**	57% **Civil works** 65% • Dam / reservoir • Tunneling / canal • Site access infrastructure • Powerhouse **Balance of system** 25% • Control systems • Grid interconnection **Other costs** 10% • Project consultancy • Planning / feasibility / permitting costs	20% **Fixed costs** • Routine component and equipment maintenance (e.g. replace pitted turbine blades; generator rotor and bearings) • Operations labor • Insurance **Variable costs** • Unplanned maintenance • Incremental servicing costs

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TABLE B1. Renewables value chains *(continued)*

Technology	Major Equipment	EPC	O&M
Geothermal	32% **Power plant** • Turbine • Heat exchanger	45% **Civil works** 40% • Drilling • Powerhouse / surface facilities • Site access infrastructure **Balance of system** 30% • Steam gathering • Control systems • Grid interconnection **Other costs** 30% • Exploration and resource confirmation • Project consultancy • Planning / feasibility / permitting costs	23% **Fixed costs** • Routine component and equipment maintenance • Operations labor • Insurance **Variable costs** • Unplanned maintenance (e.g. well replacement drilling) • Incremental servicing costs
Bioenergy	42% **Feedstock conversion system** 80% • E.g. boiler / gasifier / gas collection system **Prime mover** 20% • Power generation technology	27% **Civil works** 30% • Construction costs • Site preparation • Building construction **Balance of system** 50% • Fuel handling / preparation • Control systems • Grid interconnection **Other costs** 20% • Project consultancy • Planning / feasibility / permitting costs	32% **Fixed costs** • Routine component and equipment maintenance • Operations labor • Insurance **Variable costs** • Ash disposal • Unplanned maintenance • Incremental servicing costs
Biofuels	46% **Major equipment** • Milling / crushing components • Cooking tanks • Centrifuges • Drying systems • Boilers • Thermal oxidizers • Distillation & evaporation columns	27% **Civil works** • Construction costs • Site preparation • Building construction **Balance of system** • Piping • Rolling stock • Forced air • Water treatment / digesters • Storage tanks • Chemicals, enzymes, yeast • Denaturant **Other costs** • Project consultancy • Planning / feasibility / permitting costs	27% **Fixed costs** • Routine component and equipment maintenance • Operations labor • Insurance **Variable costs** • Energy costs • Effluent treatment & disposal

TABLE B2. Water and sanitation value chains

Technology	Major Equipment	EPC	O&M
Water	68% **Purification** • Filters • Testing & monitoring equipment **Distribution and Storage** • Pipes • Tanks • Water towers and pumps **Watershed management** • Reservoir facilities • Monitoring instruments	27% **Purification** • Sales, delivery & installation **Distribution and Storage** • Pipe laying • Sales, delivery & installation • Civil works / construction **Watershed management** • Civil works / construction • Installation & calibration	5% **Purification** • Scheduled filter replacement • On-going testing & monitoring **Distribution and Storage** • On-going delivery • Replacement parts **Watershed management** • Reservoir management • Data processing & logistics
Wastewater	40% **Collection** • On-site collection (septic tanks, on-site cesspools, septage removal trucks) **Treatment** • Sewage treatment plants • Industrial treatment plants • Agricultural wastewater management **Final disposal** • Dewatering equipment • Processing equipment for reuse or landfill/incineration	50% **Collection** • Civil works (construction) • Sales, delivery & installation **Treatment** • Civil works (construction) • Sales, delivery & installation • Management of erosion, nutrient runoff, & IPM **Final disposal** • Sales, delivery & installation • Retailing of processed sludges	10% **Collection** • Infrastructure maintenance • Trucking/transport upkeep **Treatment** • Plant operations & maintenance • Chemicals and enzymes • Land management **Final disposal** • Equipment operations & maintenance
Municipal solid waste	18% **Collection & recovery** • Collection vehicles • Communal bins **Sorting** • Sorting equipment (manual and mechanical) **Treatment** • Recycling facilities • Organic waste facilities **Final disposal** • Sanitary landfill construction • Incineration equipment	23% **Collection & recovery** • Strategic planning • Sales & delivery **Sorting** • Civil works and on-site construction **Treatment** • Civil works and on-site construction **Final disposal** • Civil works and on-site construction	59% **Collection & recovery** • Vehicle operations & upkeep **Sorting** • Sorting facility upkeep **Treatment** • Waste management and recycling facility operations **Final disposal** • Landfill operations (leachate / methane management) • Monitoring

TABLE B3. Transport value chains

Technology	Major Equipment	EPC	O&M
Natural gas vehicles	**95%** **Natural gas conversion kit** • Tank • Cylinder • Vapor bag • High pressure pipe • Refueling valve • Pressure regulator • Gas-air mixer • Petrol-solenoid valve • Selector switch	**5%** **Labor** • Mechanic	**0%** **n/a**
Electric vehicles	**100%** **Entire electric vehicle**	**0%** **n/a**	**0%** **n/a**
Electric bikes	**81%** **E-bikes** • Cost of an e-bike	**18%** **E-bikes** • Battery replacement	**1%** **E-bikes** • Equipment maintenance • Labor
Bus rapid transit	**15%** **Buses**	**35%** **Bus system** • Bus station • Bus terminal • Control center • Roadway construction	**50%** **Buses** • Bus maintenance **Bus system** • Upkeep of infrastructure

Photo: World Bank.

Appendix C. Policy Options and Instruments

TABLE C1. Entrepreneurship and business acceleration

Name	Description of collaboration	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Startup or innovator networks	A network of SME innovators or "startups" aiming to share ideas and facilitate access to markets and investors	A more business-oriented means to achieve the same intended outcomes as bilateral and multi-lateral agreements and partnerships to incubate clean technology SMEs and/or connect investors with business opportunities, mostly in developing countries.	Effectiveness is linked to establishing relevant relationships and trust-building	Brazil's Centre for Innovation, Entrepreneurship and Technology (CIETEC)[27] was set up in 1998 by the Secretariat of Development of the State of São Paulo and the São Paulo Micro and Small Enterprise Support Service. It is hosted at the University of São Paulo and has the capacity to support 120 technology-led firms through the pre-incubation, incubation and post-incubation phases.
Management and entrepreneurship training	Targeted capacity building for entrepreneurs and managers operating in, or planning to develop, clean technology SMEs	Enterprise development, that is, business skills capacity development, is often an integrated part of donor-backed projects to help push clean technology SME ideas and opportunities in developing countries. Such programs are most valuable in developing countries where general business skills and/or awareness regarding clean technology opportunities may be lower.	Normally a short-term, project-based, development cycle as a prerequisite for access to soft loans	GVEP's €4 million Developing Energy Enterprises Project (DEEP),[28] supported 900 "bottom of the pyramid" micro and small businesses across East Africa with mentoring, training and support services covering product quality and technical issues, business and sales skills, access to finance and business networks.

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27 For a detailed study of startup and innovator networks in Latin America, see OECD (2013) "Startup Latin America: Promoting Innovation in the Region." www.redue-alcue.org/redue/documentosredue/StartupLatinAmerica.pdf

28 For a summary of the DEEP project (2008-2013), see: www.gvepinternational.org/sites/default/files/deep_booklet_2013_0.pdf

TABLE C1. Entrepreneurship and business acceleration *(continued)*

Name	Description of collaboration	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Multilateral support for clean technology entrepreneurs	Programs to support specific clean technology startup SMEs and enhance business environments	Can be cooperation or competition-based methods to identify clean technology entrepreneurs and connect them to potential investors, partners and markets. Various programs focus on capacity building and business skills development, spanning sectors and technologies.	Can be short or long term	Key initiatives include the GEF-UNIDO Global Clean technology Program for SMEs[29] and World Bank *info*Dev's Climate Innovation Centers.[30] Both have been building up work programs and capacities in developing countries since 2011.
National or multilateral public-private partnerships	To link investors with clean technology opportunities in developing countries	There is a tendency for such agreements to operate at higher levels, involving governments and large corporate players. However, as with bilateral agreements, these are be designed or reformed to incorporate SME players. However criteria and terms of reference will have to reflect sector and market characteristics.	Effectiveness is linked to establishing relevant relationships	The Private Financing Advisory Network (PFAN) is a multilateral, public-private partnership initiated by the Climate Technology Initiative (CTI) in cooperation with the UNFCCC Expert Group on Technology Transfer. PFAN aims "to bridge the gap between investments and clean energy businesses."[31]
Official development assistance (ODA)	Public spending by OECD governments on assistance to developing countries to implement sustainable development	ODA is increasingly directed at climate change mitigation and adaptation programs, in continued recognition of the relationship between environment and poverty. As such there is significant scope for program developers to integrate clean technology SMEs into their work plans, including capacity building and soft financing, as a key means to address develop goals.	ODA funding and project tend to follow multi-year cycles	Danida (Danish development assistance) runs "Business Partnerships," providing financial support for the "preparation and implementation of commercially oriented partnerships" between Danish companies and partners in developing countries.[32]

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29 See: www.thegef.org/gef/sites/thegef.org/files/publication/GEF-UNIDO_GlobalCleantech.pdf

30 See: www.infodev.org/articles/cicbusinessplans

31 See: www.cti-pfan.net

32 Danida Business Partnerships: http://um.dk/en/danida-en/activities/business/partnerships/

TABLE C1. Entrepreneurship and business acceleration *(continued)*

Name	Description of collaboration	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
UN-led initiatives to enable technology transfer	Primarily technical assistance for clean technology "readiness," donor-funded but country-led	Funding is in place under the UNFCCC's Technology Mechanism, providing country-specific technical support for low-carbon and climate resilient development. Interventions are country-led and so there is plenty of scope to involve SMEs. However the longer-term impacts depend upon the delivery of large-scale funds for investments that enable technology transfer to developing countries.	Ongoing and linked to UN-chaired negotiations under the global Climate Convention	The Climate Technology Centre and Network (CTCN) is the operational arm of the UNFCCC Technology Mechanism providing technical assistance to developing countries, in support of their low-carbon and climate-resilient development plans. This will be provided through 11 expert organizations located in developing and developed countries, as of 2014.[33]
Knowledge platforms	Designed to promote knowledge sharing on both technical inputs and project/business implementation (that is, "good practice")	Can be valuable when focused and well structured, however success depends upon positive reputation and the achievement of "go-to" status. This is challenging given the plethora of online knowledge platforms.	Ongoing, built up over time	International Cleantech Network,[34] hosted by the Copenhagen Cleantech Cluster; Climate and Development Knowledge Network (CDKN)[35]

33 See: www.unep.org/climatechange/ctcn/

34 See: http://internationalcleantechnetwork.com/

35 See: http://cdkn.org/

TABLE C2. Innovation finance

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Loan guarantees[36]	Can be commercial business loans issued by private banks, though with the backing of State funds to share the financial risk and provide typically <100 percent guarantees in case of default, or State-backed specialist lenders	Targeted, that is, subsector-specific, schemes are more effective. Dual approval processes for technical and commercial criteria can reduce business default rates. Markets can be developed for guaranteed loans, however the State must intervene to provide an independent guarantee approval process, so as to minimize risk of moral hazard.	Guaranteed loans can be issued from anywhere between 3 months to 10 years	The Central American Renewable Energy and Cleaner Production Facility (CAREC) provides "mezzanine" financing to small grid-connected RET projects, with a loan guarantee facility provided by the United States Agency for International Development (USAID), Development Credit Authority (DCA).[37]
Business soft loans	State or multilateral-subsidized loans given to SMEs on preferential terms, that is, less than market interest rates, lower or no collateral requirements and/or repayment grace periods	A very important means to assist clean technology SMEs, especially in Less Developed Countries where financial markets are often closed to smaller players or exact prohibitively high interest rates and stringent lending terms. Soft loans carry a lesser degree of moral hazard risk than providing soft loans, however legal certainty regarding debt liability is desirable.	Normally subject to negotiation, but not dissimilar to timeframes for commercial loans	UNEP's African Rural Energy Enterprise (AREED) provided concessional loans to more than 60 clean energy SMEs across 5 African countries, totaling approximately $5 million between 2003 and 2012[38]
State-funded venture capital and equity guarantees	Where public funds are used to invest in unproved or far-from-market technologies, often in exchange for a share of future business ownership (equity)	Can provide capital investment, on more favorable terms than private VC, to support early-stage innovating clean technology SMEs. However they run a high risk of failure by backing technologies that have not been backed by commercial risk capital. Also a tendency for public equity guarantees to be offered for low quality and/or high-risk investments, thus increasing failure rates.	Are normally non time-bound and based on acceptance of the business plan	China's Shenzhen Capital Group[39] is one of China's most successful state-controlled venture capital groups, pioneering the Government Sponsored Fund structures, investing in a range of technology startups including clean technologies.

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36 For a comprehensive overview, see: "SME Credit Guarantee Schemes in Developing and Emerging Economies: Reflections, Setting-up Principles, Quality Standards" published by GTZ (2012) www.aecm.eu/servlet/Repository/giz-study-on-smes-credit-guarantee-schemes.pdf?IDR=553

37 For more information on the Central American Renewable Energy and Cleaner Production Facility, see: www.iadb.org/en/projects/project-description-title,1303.html?id=rg-m1002

38 For a detailed study on the AREED project see: Haselip, J., Desgain, D. and Mackenzie, G. (2013) "Energy SMEs in sub-Saharan Africa: Outcomes, barriers and prospects in Ghana, Senegal, Tanzania and Zambia." http://orbit.dtu.dk/fedora/objects/orbit:121830/datastreams/file_0c82ddc4-488c-4ac1-95b4-dba29ea1a29a/content

39 Portal for Shenzhen Capital Group: www.szvc.com.cn/Default.aspx

TABLE C2. Innovation finance *(continued)*

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Targeted consumer credit	Commercial or subsidized lending to household or commercial consumers for specific clean technology products	Can help overcome demand-side barriers to clean technology products with relatively high up-front capital costs, where banks have either blocked loans or charged high rates for unknown products that were perceived as right risk. Tailoring technology-specific loans, rebates or tax credits builds specific knowledge within banks, enables more accurate risk assessment and cheaper financing.	Can be developed as a short-to-medium term bridge to "normalize" commercial lending	Tunisia's consumer credit facilities for solar water heaters[40] (SWH) have been a key means to boost demand and lower system costs, working in partnership with multi-lateral agencies and local banks.

40 For a detailed study of Tunisia's PROSOL programme to support SWHs, see the Climate Policy Initiative (2012): http://climatepolicyinitiative.org/wp-content/uploads/2012/08/Prosol-Tunisia-SGG-Case-Study.pdf

TABLE C3. Market development

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Sector-specific government standards	Can be applied to a range of sectors to pull demand for clean technology, from energy efficiency in buildings to biofuel mixing	Government-imposed performance standards are a key means to influence the pace of innovation and technological change in specific sectors, driving demand for clean technology products and services. The main challenge is to steer a course beyond business as usual, balancing ambition and realism. Most effective standards are developed in partnership with local industry, charting a clear, long-term transition that will ensure future market demand.	Medium to long-term, with clear year-based targets	Thailand's 1992 Energy Conservation Promotion Act (subsequently revised) initiated demand for efficient lighting, air-conditioning, and hot water generation and solar energy systems, as well as the construction of energy efficient buildings (envelope).[41]
Manufacturer standards and product labeling	A standard for the purchase or manufacture of appliances that meet certain environmental performance	Manufacture and/or performance standards and labeling have proved to be a powerful means of driving demand for clean technologies, in particular energy efficient consumer goods. Success is achieved by means of communicating simple information, offering "win-win" benefits and raising consumer consciousness. However their power depends upon wide recognition of the standard, thus limiting the scope for new standards.	Once established, performance criteria must tighten over time so as to drive further innovation and investment to improve performance	The Energy Star standard is the most successful international label for energy efficient consumer goods which offer efficiencies of at least 25 percent above the United States federal standards and has been adopted by the EU and most other OECD countries.[42]
Product testing and certification	Aims to level the playing field between businesses and ensure quality control. This can be done either by national governments or international agencies.	In embracing quality control and certification schemes, governments can support local clean technology SMEs that would otherwise face stiff competition from low-cost and low-quality imported goods, thus maintaining or improving technology reputations. Can work in partnership with product labeling initiatives, but success depends upon a significant degree of consumer awareness to make informed decisions.	Requires strong, sustained support and market regulation	IFC/World Bank's Lighting Africa initiative supports "Lighting Global" quality verification of solar lamps, where approved products commanded about a third of Africa's off-grid lighting market in 2012.[43]

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41 For a detailed study of energy efficiencies driven by Thailand's government-set building standards see: Chirarattananona, S. et al. (2010) "Assessment of energy savings from the revised building energy code of Thailand," *Energy*, Vol.35 (4) p. 1741–1753.

42 For more information on Energy Star and qualified products, see: www.energystar.gov/index.cfm?fuseaction=find_a_product

43 See here for more information about Lighting Global's minimum quality standards: www.lightingglobal.org/activities/qa/standards/

TABLE C3. Market development *(continued)*

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Renewable Energy Portfolio Standards or Obligations and Renewable energy certificates (RECs)	Obligations or portfolio standards are government-imposed mandatory targets for utilities to generate X percent of their power from RETs. This normally results in the creation of certificates which can "surrendered" or traded, providing a market-based subsidy.	Portfolio standards (or obligations) tend to drive price competition between different RETs, however they often fail to support import but more expensive technologies, such as solar PV. In order to stimulate investment in renewable energy capacity, the demand and price for RECs has to be high. While RECs are a market mechanism, prices are largely influenced by the regulatory framework that creates them. Therefore the penalties for noncompliance must be significant, and floor prices should not be set so low that the value of RECs becomes of marginal importance.	As with all market mechanisms, the effectiveness of RECs depends upon sustained government commitment.	RE portfolio standards and obligation have been used in the United States, United Kingdom and Sweden as an alternative to feed-in tariffs and have succeeded in supporting mostly onshore wind power. RECs have been traded in India[44] since 2011 however market participation has been low and has failed to attract significant investment.
Feed-in tariffs (FITs)[45]	Provide a minimum guaranteed price paid by utilities to all generators of electricity from renewable energy, supplying the grid. The exact value of tariff support is set by government, usually for a fixed time period, and tends to vary according to the type of generation technology.	Simpler than RECs, FITs have been successful in many OECD countries, driving markets for wind and solar power where SME participation is high for installation and operation. They are unlike conventional subsidies in that they are intended to spur market and technological development, driving cost reductions in the process, normally by tapering tariff over time. FITs are conceptually very simple and easy to administer, offering clear financial risk management for investors. However, once renewables take up a larger share of the generation market place, fixed-price (as opposed to market-based) FITs can become expensive and harder for governments to justify.	The number of years offered by the FIT is of fundamental importance and can range from 5-30 years	80+ countries worldwide have legislated FITs, however the vast majority of RET investments supported by FITs has been in developed countries. This is partly because of the rapid uptake of FITs in developing countries since 2009, following which there is a delay during projects are designed and investors are mobilized.[46]
Advanced market commitment	A legal contract between public or private entities that guarantees the purchase of a technology, subject to meeting minimal, pre-defined, performance requirements	A means to minimize investment risk in important but unproven technologies, where payment is only made upon delivery. To date has only been used for the development of medicine and is most relevant in addressing specific technical problems or requirements. Of minimal relevance to clean technology, and its effectiveness diminishes along with a high degree of technological uncertainty.	Technology-specific and time-bound	Pneumococcal Vaccine supported by the Global Alliance for Vaccines and Immunization

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44 For an assessment of the first year of REC trading in India, see: www.isb.edu/download/16739/Falling-Short-An-Evaluation-of-the-Indian-Renewable-Certificate-Market.pdf

45

46 For a comprehensive overview of FITs for developing countries, see: www.unep.org/pdf/UNEP_FIT_Report_2012F.pdf

TABLE C3. Market development *(continued)*

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Sustainable procurement[47]	Purchasing policies by governments and large corporations, where decision making takes into account external environmental and social costs, in addition to financial (internal) costs	Can be a powerful means to drive demand for clean technology products and services as governments tend to be the single largest consumers in an economy. However the exact criteria can vary significantly between organization, thus consumption that is radically more sustainable than "business as usual" does not always occur.	Policy continuity drives long term demand for clean technology products and services	In 2007 the Federal government of Brazil imposed public procurement criteria to ensure the purchase of legally-certified sustainable wood products, with criteria designed to increase the participation of SMEs. However more wide-reaching and progressive social and environment criteria has been legislated by the State of Sao Paulo.[48]
Public rankings	A ranking of countries, businesses, organizations or municipalities based on the production or consumption of clean technology	As with all rankings, results are the product of context-free criteria that are unlikely to reflect fairly the performance of all target entities or jurisdictions, for the sake of comparison. While rankings can stimulate a healthy degree of competition, and hence motivation to reach specific targets, they can also have a counter-productive effect whereby the "usual suspects" (for instance, Scandinavia) dominate the rankings, thus demotivating others and having a competitive effect only at the top.	Most rankings are published yearly and obtain status and following over time	The Global Clean technology Innovation Index, published by the Clean technology Group and WWF, first published in 2012 ranked Denmark, Israel, Sweden, Finland and the United States as the top-5 countries for clean technology innovation.[49]
Campaigns	Can take many forms and be official (that is, government-led), commercial, individual or community-based and broad or specific in focus	Need to be simply, clear messages most campaigns are conducted online and can lead to "crowdfunding" (that is, a large number of small contributions), especially relevant for diaspora populations to support initiatives in their home countries	Normally short term, targeted	UNDP has supported a campaign to "crowdfund" solar energy for schools in Croatia, which demonstrated the power of campaigns and the potential of crowdfunding as a niche instrument.[50]

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47 For a generally overview of sustainable public procurement (SPP), see: http://esa.un.org/marrakechprocess/pdf/InnovationBriefs_no5.pdf

48 See Brauch, M. (2012) "Sustainable Public Procurement in the Sao Paulo State Government" www.iisd.org/pdf/2012/spp_sao_paulo_brief.pdf

49 For the full report, see: http://awsassets.panda.org/downloads/coming_clean_2012.pdf

50 For more information on this campaign, see: www.al.undp.org/content/croatia/en/home/presscenter/articles/2013/12/02/crowdfunding-campaign-for-the-first-energy-independent-school-in-croatia-to-be-launched/

TABLE C3. Market development *(continued)*

Name of instrument	Description of instrument	Evaluation	Commitment period	Example
Education	Can operate at various levels from primary to advanced, to either raise awareness about clean technology or build specific capacities	Education is fundamental to any enabling framework and potentially most powerful, influential instrument. In the case of clean technology SMEs, education can be a means to raise awareness and hence demand for clean technology products and services, though greater influence is more likely through specific courses at University level. However can be longer-term, difficult to measure impact.	Long term, sustained	Cleantech.org's "Professional Series" seminars and short courses on how to commercialize clean technology. These are online courses and hence accessible to potentially anyone, worldwide.[51]

51 See: www.cleantech.org/education.html

TABLE C4. Technology development

Name of instrument	Description of instrument	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
R&D tax credits[52]	Various forms of tax exemption or reduction granted to SMEs that pursue clean technology market opportunities	This is the primary nongrant financial incentive for SMEs to enter the clean technology sector and is an established benefit often afforded to SMEs in general, given their higher innovation rates and job creation. For the clean technology sector tax jurisdictions can extend and/or deepen the tax credits to SMEs given their positive environmental externalities.	To be effective in stimulating business ideas, plans and investment, tax credits need to be simple, clear and stable, backed by strong political commitment in the medium to long term.	South Korea's Limited Tax Incentives Law[53] offers a tax deduction for SMEs of 8-25 percent when 40 percent of current year R&D current-year R&D expenditures exceed the average over the previous 3 years. Nonetheless, the relative share of R&D investment by SMEs has decreased since 2001, despite tax regimes being more beneficial than for large firms.[54]
Research grants	Mostly public but sometimes private funding to conduct R&D in a specific area or application, normally awarded on a competitive basis by a committee of experts. Typically grants are structured into "phases," from exploratory to pre-commercial.	An important means to provide funding for early-stage business and innovation ideas that are too high risk for private investors, including venture capital. In the competition-based awards, naturally high failure rates are exacerbated by the risk of "picking winners." However this can be mitigated by support for business ideas that spin-off from University-based research.	Normally these are one-off grants with no conditions, though can be linked to the promise of next-stage financing	The multi-donor Africa Enterprise Challenge Fund (managed by KPMG) awards up to $2.5 million in grants and interest free loans to innovating SMEs in Africa, with a primary focus on climate technologies.[55] Launched in 2008 the fund has grown from $30 million to $190 million and approved 133 projects across 22 African countries.
Publicly funded competitive research collaborations	Clean technology research and innovation projects involving numerous partners to address specific, normally cross-boundary, problems	There is a trend in OECD countries to combine business, especially SMEs, into research and innovation processes where public research funding is no longer the primary domain of Universities. While this has been criticized by some for prioritizing business interests, it is likely to enable a faster rate of technology commercialization, informed by public-funded R&D.	Normally time-bound and subject to funding cycles, reflecting high-level political priorities	EU's €70.2 billion Horizon 2020 framework[56] (2014-2020) merges research and business innovation, intended to boost competitiveness of the host regions but also includes significant scope for involving University and SME partners in developing countries, to develop clean technology markets.

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52 For a summary of tax incentives for R&D and innovation, see OECD: www.oecd.org/sti/outlook/e-outlook/stipolicyprofiles/competencestoinnovate/taxincentivesforrdandinnovation.htm

53 In January 2014 Korea passed tax reforms including changes to R&D incentives, though these remain favorable to smaller businesses. See: www.ey.com/Publication/vwLUAssets/Korea_passes_tax_reform_proposals_including_several_changes_to_R_D_incentives_regime/$FILE/2014G_CM4141_KR per cent20passes per cent20tax per cent20reform per cent20proposals per cent20including per cent20changes per cent20to per cent20R per cent20D per cent20incentives.pdf

54 For a detailed study, see: Song, Jong Guk (2007) "The impact of fiscal incentives for R&D investment in Korea" www.oecd.org/sti/inno/40023738.pdf

55 For more information on the Africa Enterprise Challenge Fund (AECF) see: www.kpmg.com/eastafrica/en/services/advisory/development-advisory-services/services_and_expertise/private_sector_development/aecf/pages/default.aspx

56 See: http://ec.europa.eu/programmes/horizon2020/

TABLE C4. Technology development *(continued)*

Name of instrument	Description of instrument	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Competitions	Mostly launched by public organizations to incentivize the invention of new hardware or solutions, designed as either open competitions based on the merit of idea or to address specific technical problems or targets, normally backed by a significant financial incentive (prize money)	Can be a simple and powerful means to stimulate technical innovation and progress in specific areas, often more effective when a target-based criteria is used, for instance, to invent a light bulb that uses less than X unit of energy. Competitions are open to anyone and can have unintended positive spin-off effects, though where the scope and parameters of the competition itself is set by technical experts they may overlook more relevant or pressing targets or problems.	Normally time-bound events with an entrance deadline, depending on the nature of the challenge	South Africa's "Step-Up Technology Innovation Competition" for SMEs does not specify technology targets or sectors. It is an open competition to all technology innovations, where the prize is a combination of business development training and contact with potential investors.[57]
Public investment in R&D[58]	Fiscal spending on R&D as part of national strategy to boost clean technology, either through direct funding to SMEs or through public institutes and Universities	Has been a powerful means to boost innovation and technical capacities in many developed and emerging economies. Is most effective when markets or technologies are well-defined and in support of strategic national development goals, ideally building upon pre-existing national capacities. However can run risk of undermining market forces if designed to pick winners.	Strong top-down political commitment and stability is essential, ideally with clearly defined phase-out or exit strategies	Brazil's National Bioethanol Science and Technology Laboratory (CTBE) was set up in 2008 to build the country's competitive advantage in biofuel technologies, co-located with the Brazilian Synchrotron Light Laboratory (LNLS) and the State University of Campinas (UNICAMP) and funded by the Brazilian Ministry of Science and Technology.[59]
Public or private agreements on technology cooperation	Can be government-to-government or via trade associations	Most such agreements are designed to promote mutual interests in clean technology development and market expansion, based upon sharing of knowledge and skills. Most tend to involve larger corporate players. And while much depends on the nature of the sector, technology and type of agreement, there is certainly great scope to involve clean technology SMEs, especially for sectors with distributed operations or more complicated supply chains.	Success depends upon trust and relationship-building, so tend to strengthen over time	"Bridge Clean technology," launched in 2010 and hosted by UK-India Business Leaders Climate Group aims to "bridge the gap between businesses, technology developers, financial institutions and policy makers with the objective of promoting clean technology development, commercialization, adoption and diffusion."[60]

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57 For more information see: www.step-up.org.za

58 For more information on the role of public R&D and international Science, Technology and Innovation, see OECD (2012) www.oecd.org/sti/outlook/e-outlook/stipolicyprofiles/interactionsforinnovation/buildinginternationalstilinkages.htm

59 Portal for Brazil's National Bioethanol Science and Technology Laboratory (CTBE): www.bioetanol.org.br/english/

60 See: www.bridgecleantechindia.com

TABLE C4. Technology development *(continued)*

Name of instrument	Description of instrument	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Demonstration projects	Specific clean technology projects, normally backed by national or multi-lateral public funds to demonstrate feasibility of near or far-from-market technologies	If well designed can be of strategic value, accelerating learning-by-doing and rapidly reduce future project cost with high visibility leading to public acceptance. However can be overly expensive and/or demonstrate failures and well as successes, translating into political risks that may be counter-productive.	Only necessary for the duration of the project itself, though makes sense if there is wider strategy or commitment to develop and apply the technology in the demonstration country	Turkey's International Centre for Hydrogen Energy Technologies[61] (2003-2012), funded by UNIDO and the Turkish Government, provided technical and financial support to the development and implementation of hydrogen energy demonstration projects, conducting applied R&D for developing countries, training and education programs.
Applied Research Networks	A network of researchers focusing on applied topics, in either North-South and South-South collaborations	A proven means to conduct important problem-driven research, based on knowledge and resource sharing between developed and developing countries and to avoid duplication of data gathering and analysis	Effectiveness is linked to establishing long-term relationships	The CGIAR[62] umbrella group funds and co-ordinates research via 15 organizations, mostly based in developing countries, into sustainable agriculture and forestry enabling a high degree of knowledge sharing.

61 For more information on Turkey's International Centre for Hydrogen Energy Technologies, see: www.unido.org/en/what-we-do/environment/energy-access-for-productive-uses/energy-and-climate-change/global-forum-activities/energy-technology-centers/international-centre-for-hydrogen-energy-technology.html

62 See: www.cgiar.org/

TABLE C5. Legal and regulatory framework

Name of instrument	Description of instrument	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Cap-and-trade emission schemes	The trading of permits, normally between private entities, for the right to emit X tones of industrial gases (CO_2, SO_2, NO_x) or extract natural stock (for instance, fishing quotas), subject to a nationally-set limit (cap)	This is the most common market mechanism to incentivize investment in clean technology, popular with both governments and businesses in OECD nations for the ease of administration. However unless the caps are revised in line with technological change and economic growth then the price signals may be too weak to influence investment behavior. More effective if permits are auctioned instead of being given away, within a broad cap so as to present "leakage." Furthermore, it is difficult for developing countries to implement ETS and offset schemes as many don't have the data or capacity to establish GHG emissions baselines and projections.	To be effective cap-and-trade systems need to be in place indefinitely, with clear indications that caps will become tighter over time	European Union's Emissions Trading Scheme (EU-ETS) is the world's largest and longest-running, covering around 12,000 industrial installations responsible for 45 percent of the EU's total GHG emissions.[63] Similar schemes are operating or planned in emerging markets, for example in China where 7 cities are launching their own ETS, starting with Shenzhen which covers 635 installations.[64] However no ETS has, as of 2013, managed to push carbon prices up to levels likely to stimulate significant investment in climate mitigation technologies, mainly because of weak caps.
Emission Reduction Credits[65]	A system where businesses are rewarded for reducing emissions below a baseline, usually intensity-based (for instance, CO_2 emissions per unit of production). These reductions are converted into tradable credits where liable parties must purchase credits and then surrender them to the regulator at the end of each year, to meet their share of an economy or sector-wide reduction targets.	As with cap-and-trade systems, baseline-and-credit trading can provide simple economic incentives to invest in clean technology. However since baselines are normally set against intensity targets, increases in total production can outweigh the emissions reductions. Furthermore, it can be difficult to establish "additionality," that is, to know if the emissions reductions awarded credits under the scheme would have occurred anyway.	To be effective in reducing emissions in the long term, baseline-and-credit trading needs to be followed with long-term commitments by all countries to reduce absolute emissions levels	The Clean Development Mechanism[66] (CDM) is the best known example of the trade in Emission Reduction Credits, which issues 1 billion Certified Emission Reductions (CERs) credits between 2001 and 2012. However the price of CERs collapsed to below 1 EUR by 2012 following huge oversupply in the EU-ETS and the failure to secure a post-Kyoto agreement on global reductions. Furthermore, 60 percent of CERs have been sold by Chinese companies for the destruction of non-CO_2 gases, as opposed to investment in low-carbon technologies.

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63 For detailed analyses of the EU"s ETS see: www.carbontrust.com/resources/reports/advice/eu-ets-the-european-emissions-trading-scheme

64 For a summary of the Shenzhen pilot ETS see: www.economist.com/blogs/analects/2013/06/carbon-emissions

65 For a succinct explanation of Emission Reduction Credits, see the Australian government's Department of Environment (2010) guidance on "Baseline and credit schemes" http://climatechange.gov.au/sites/climatechange/files/files/reducing-carbon/mpccc/baseline-credit-scheme-pdf.pdf

66 For detailed analysis of CDM projects in emerging economies and developing countries, see: http://cdmpipeline.org/cdm-projects-region.htm

TABLE C5. Legal and regulatory framework *(continued)*

Name of instrument	Description of instrument	Evaluation *(summary of strengths / weaknesses)*	Commitment period	Example
Taxation on pollution or natural resource use	Taxes can be levied on specific pollution outputs or on the abstraction or consumption of natural resources including water user fees, wastewater discharge fees, and solid waste disposal fees	Born out of the "polluter pays principle," that is, that a company causing pollution or resource extraction should pay for the cost of removing or replacing it, or provide compensation to those who have been affected. While such taxes can raise revenue streams to finance clean technology ventures and business development they do not, unlike market-based mechanism, ensure pollution reductions. Rather they simply penalize unsustainable behaviors, which may not trigger investment in clean technologies.	As with most fiscal measures, its effectiveness depends upon sustained government commitment	Among developing countries, India introduced a carbon tax in 2010, though only for coal, charged at $1.07 per ton either produced in or imported to India.[67] South Africa, as another carbon-intense developing economy, has embraced the idea of a carbon tax, though has delayed implementation until 2016.[68]
Import tax reductions or waivers	Key fiscal measure that can be targeted for specific clean technology imports	Can assist clean technology SMEs that depend upon the importing of specific, often high-tech, inputs. Most relevant to Less Developed Countries. A main challenge is to maintain an up-to-date list of technologies and associated equipment (such as inverters used for PV systems) that is fair and not open to abuse by traders who would avoid tax but use the equipment for other, that is, nonclean technology, sectors.	As with most fiscal measures, its effectiveness depends on stable and long-term commitment from government	Senegal's 2010 Renewable Energy (RE) Law includes a 0 percent corporate income tax (normally 30 percent) for investors in RE and 0 percent VAT (normally 7 percent) for RE products and services, which has been of particular benefit to the solar PV market.[69]
Attracting talent ("sticky cities")	Government policy to attract and retain talent and human capital through income tax breaks	Aims to attract creative and scientific talent for clean technology, especially relevant for less developed countries that have suffered a "brain drain." However needs to be implemented in concert with other enabling policies and also to significant enough to trigger a flow of talent to be successful. Policy risk is higher in the countries that would stand to benefit most and eligibility requires strict oversight so as to avoid gaming.	Strong top-down political commitment and stability is key to effectiveness	Various African governments committed to the idea under the New Partnership for Africa's Development (NEPAD), though it has mostly been implemented on an ad-hoc basis with no formal mechanisms in place or means to measure impact, to date.

67 Information on country carbon taxes is compiled by KPMG: www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/green-tax/Documents/kpmg-green-tax-index-2013.pdf

68 News report of the South African government's 2014 decision to delay carbon taxation until 2016: www.bloomberg.com/news/2014-02-26/south-africa-delays-carbon-tax-plans-levies-on-acid-mine-water.html

69 See Senegal's 'Renewables Readiness Assessment' (2012) published by the International Renewable Energy Agency (IRENA) www.irena.org/DocumentDownloads/Publications/IRENA per cent20Senegal per cent20RRA.pdf

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