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The Applied Research Programme on Energy and Economic Growth (EEG) is led by Oxford Policy Management in partnership with the Center for Effective Global Action and the Energy Institute @ Haas at the University of California, Berkeley. The programme is funded by the UK Government, through UK Aid. Over the course of five years, EEG will commission rigorous research exploring the links between energy economic growth, and poverty reduction in low-income countries. This evidence will be specifically geared to meet the needs of decision makers and enable the development of large-scale energy systems that support sustainable, inclusive growth in low income countries in South Asia and Sub-Saharan Africa.

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Energy and Economic Growth
Theme 4, Paper 2
Economic and non-economic barriers and drivers for the uptake of renewables

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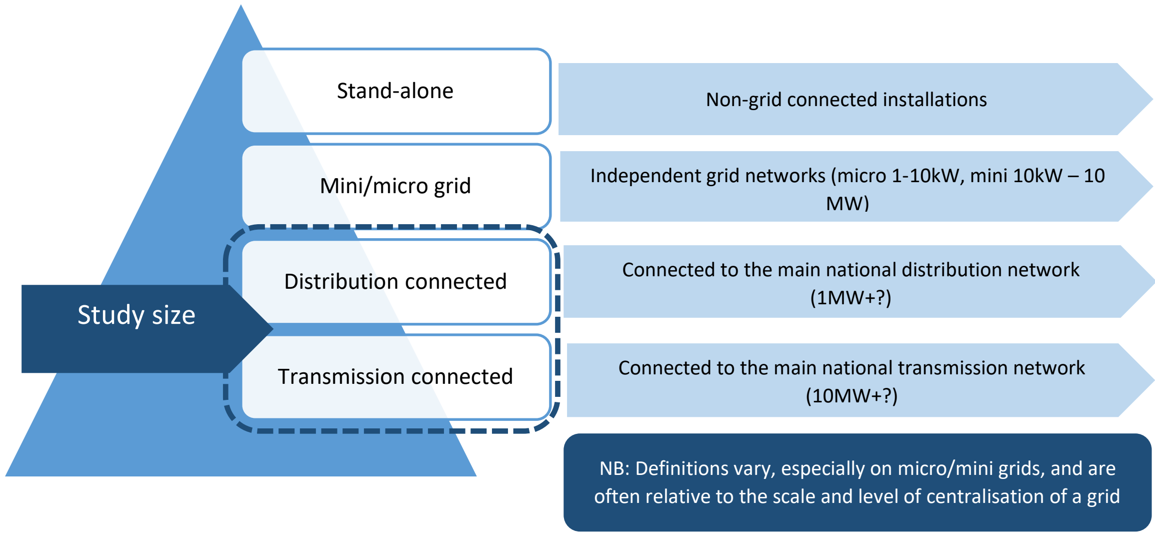
Scope

In recent years, large-scale renewable energy technologies (RETs) have become a mainstream investment choice in many world regions, including some developing countries (REN21 2015, International Energy Agency (IEA) 2015, International Renewable Energy Agency (IRENA) 2016). The most recent edition of the United Nations Environment Programme (UNEP) Global Trends report puts China, India, Brazil (the 'Big Three') and South Africa in the top 10 countries for investment for 2015 alongside the more traditional developed economies (Frankfurt School *et al.* 2016). Largely driven by activity in China, and coupled with a fall in investment in developed economies, overall investment in renewables in developing countries outweighed that in developed countries.

However, while these rapidly growing economies are currently leading the way, the growth of renewable generation is patchy across sub-Saharan Africa (SSA) and south Asia (SA), with some countries performing well and others lagging behind. Many but not all countries in SSA and SA have renewable power targets and policy mechanisms in place at national or subnational/state level to encourage renewables deployment. This indicates that there is a degree of political will in those countries to encourage the use of renewables, whether for environmental, economic, access or security reasons. However, the actual uptake of renewable electricity technologies is determined by a number of economic and non-economic conditions acting as either drivers or barriers in addition to political commitment. It is important to stress that each of the countries in these regions has unique approaches to electricity system design, infrastructure requirements and available renewable resources; each country will therefore have its own individual responses to the drivers and barriers to greater renewables deployment.

This paper considers the drivers and barriers faced by 'large-scale' renewables in electricity systems in developing countries in the short and longer term. By 'large scale' we mean here renewable projects that are connected to distribution or transmission networks, and which are therefore able to participate in power markets. This definition avoids setting a limit in terms of the total capacity of any individual project, but instead focuses on the ability to sell power, whether by contract to a utility or into a power pool. It excludes stand-alone, very small-scale projects that are off-grid, and some projects connected to mini-grids if those grids are not connected to the larger national network (Figure 1). This paper considers the current state of knowledge in relation to renewables, specifically with hydro, wind and solar technologies and geothermal power.[1]

Figure 1: Defining 'large-scale' renewables



Different RETs have very different characteristics, both in terms of their impact and their operation. With the exception of large-scale hydro (often classified as >100MW[2]), grid-connected projects tend to be smaller scale than 'conventional' fossil fuel generation. Even at grid scale, wind and photovoltaic (PV) installations are often smaller, modular projects (e.g. numerous wind turbines make up a wind farm). With the exception of geothermal and biomass, they operate variably: wind and PV on a short term, day-to day basis, and hydro according to seasonal fluctuations in rainfall. The siting of projects is resource-dependent, for example where wind speeds are most reliable or where geothermal or water resources are located. This in turn requires grid infrastructure to be built where the renewable resources are. They also differ in investment profile, with high up-front capital costs compared with fossil fuel plant and relatively low operation and maintenance costs, including zero fuel costs (apart from biomass). The potential for modular, incremental investment means that renewable projects can be scaled up over time, rather than being built in one go as with conventional generation.

The starting point for this paper is that electricity systems, as with other large technical systems, are complex and multidimensional, incorporating interrelated social, economic, political and legal aspects as well as the technical characteristics of the system. Purposive action to encourage

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1 Biomass is a widespread and often dominant fuel in many developing countries, but we have not included it for two reasons. First, because the operations of biomass power plants tend to reflect the operating characteristics of conventional fossil fuel plants, and so do not pose the same challenges to system operation as more variable plant. Second, because the broad sustainability issues raised by biomass burning for electricity generation seem beyond the scope of this project.

2 There is no commonly agreed definition of 'large-scale' hydro. IRENA uses a definition of >10 MW, while the US Department of Energy uses >30 MW and the IEA >300 MW. This lack of agreement reflects the fact that whether a project is 'large' scale or not is context dependent, both in terms of a country's overall electricity system and in terms of the project's impact on a river. Non-large-scale hydro tends to be classified as medium, small and micro, although again there are no agreed definitions.

renewables deployment needs to acknowledge this complexity, by ensuring that economic, political and institutional conditions create an 'enabling environment' that supports the technical choices being made (IPCC 2012). Action and governance also need to be flexible enough to adjust to shifting conditions in the enabling environment over time. For example, increasing levels of renewables deployment may ultimately require technical and operational changes in electricity networks.

The paper is structured as follows. The next section outlines some of the key strategic drivers for increased levels of renewable generation from a high-level policy perspective. We also describe some of the main policy mechanisms in place to support renewables in many countries in SSA and SA. However, the existence of these support mechanisms may not be sufficient in itself to deliver increased growth in renewables, as decisions to invest in any project are driven by an assessment of the conditions in the broader environment, which may or may not include elements of financial risk (IPCC 2012, Hamilton and Zindler 2016). We therefore set out the different factors that may influence an investor's decision. The final section considers possible ways forward in policy and governance, both in the short term and from a longer-term, more strategic perspective.

Why choose renewables?

There are three key strategic benefits from encouraging the deployment of renewable technologies: energy security, sustainability, and economic development and competitiveness (IPCC 2012, Duscha *et al*. 2016, IRENA 2016a). Some key points relating to these areas are outlined briefly below.

Energy security

In the context of developing countries, security of supply can be improved by renewable energy in two ways: first, renewables can contribute to expanding access to electricity, for households, industry and business. This issue of energy access is particularly acute in SSA and SA, which account for 88% of the people estimated to be without electricity globally (International Bank for Reconstruction and Development (IBRD) *et al*. 2015).

Second, renewables deployment can contribute to security by reducing dependence on imported fossil fuels, although this has to be balanced against the fact that some renewable technologies – wind and solar – provide variable generation, which at high levels of deployment can have impacts on grid stability.

Sustainability

Renewables help to mitigate greenhouse gas emissions from the power system. Increasing attention is also being given to the local air pollution impacts of electricity generation, such as the emission of sulphur dioxide and nitrogen oxides from coal-fired power stations. The immediate health impacts of these emissions can be considerable: for example, around 590,000 premature deaths in India in 2015 are associated with outdoor air pollution, and air quality is becoming an increasingly politically important issue (IEA 2016d). Again, non-biomass renewables can contribute to avoiding emissions of fossil fuel-related pollutants.

As with any electricity generation technology, renewables do of course entail some environmental impacts. These can be relatively minor and short lived (for example, the visual impact of PV) to slightly more severe (such as the wildlife impacts of wind turbines). The most contentious technologies are biomass (largely because of land-use issues) and large-scale hydro projects, which can have significant environmental and population impacts (World Bank 2009). However, there are enormous untapped hydropower resources in both SSA and SA. As a result, there have been moves in recent years to develop large-scale hydro plants in some countries as a way of driving economic development and limiting a growth in carbon emissions while also managing the social and environmental risks. For example, the World Bank and other development agencies have revived interest in lending programmes for large hydro projects in the Democratic Republic of Congo (DRC), Zambia and Nepal.

Economic development and competitiveness

Finally, the creation of new industries and jobs for technology providers as well as the service sector can be a motivation for the promotion of RETs in many countries.

As with any energy technology, the employment impacts of renewable energy are complex and difficult to generalise. Data can also be scarce for individual counties, and even if they are available can lack detail of employment at all stages of the full value chain of a renewable energy project from project planning to manufacturing, operation and decommissioning (IRENA 2014b). Furthermore, such data do not necessarily reflect the quality of the jobs created. It should also be highlighted that different RETs will have different employment profiles: for example, the construction of a hydro dam is likely to imply more construction jobs over a longer time period than a wind farm, and operation of a solar PV installation is likely to require less maintenance than a wind farm simply because there are no moving parts (Blyth *et al*. 2014).

The relationship between renewables and other energy technologies is also complex. On the one hand, employment in the renewables sector is growing. IRENA estimates that direct and indirect employment in renewable energy globally was 8.1 million, with an addition 1.3 million employed in large hydropower (IRENA 2016a). Studies of employment in different energy sectors have tended to conclude that renewables generate more jobs per unit of energy generated than fossil fuels (Kammen *et al*. 2004, Wei *et al*. 2010). Blyth *et al*. (2014) estimate that investing in new renewables capacity can create one full-time job per annual GWh produced compared with gas or coal-fired plant. If demand for RETs grows as anticipated, countries with manufacturing expertise in particular could expect to benefit from the competitive advantage of being an early mover (Fankhauser *et al*. 2008).

However, on the other hand the increased use of renewables for generation is beginning to displace conventional (coal) generation in some countries with high levels of renewable deployment. This can in turn lead to job losses in the conventional energy sector and potentially higher energy costs, which may impact employment in the broader economy. Conversely of course, if renewable energy costs are lower than conventional generation, then the impacts on the economy can be beneficial. A key question is therefore not whether increased levels of renewables deployment can create jobs but whether they can create a net increase in quality, long-term jobs once possible losses elsewhere are taken into account. Evaluating this question definitively will require an examination of a range of variables, encompassing the economics of the whole value chain for renewables and other technologies in any given country.

Given these knock-on effects on employment, it could be argued that energy policy – regardless of the technology – should not be based on the jobs created within the energy sector itself (Borenstein 2015). There is an economic logic to this in the short term, but some countries are taking a longer-term, more strategic view of the role of policy in encouraging growth and employment and incorporating renewables into industrial policy. This is discussed further later in the paper.

Technology costs

Coupled with the recognition that renewables can deliver strategic benefits, the rapid decline in costs for some technologies means that renewables are no longer an extraordinary investment decision in many cases.

Hydro power has been a mainstream investment option for decades in areas of SSA and SA. Other RETs are newer, less developed and often considered as riskier investment options compared with conventional generation. However, costs for these new technologies have fallen rapidly in recent years and in some circumstances they may already be competitive or very close to competitiveness with conventional alternatives, although this depends heavily on the resource conditions of the region and the costs of financing construction.

The investment costs (per kW) of solar PV modules and wind turbines decreased by about 80% and 30% respectively between 2009 and 2015 (IRENA 2016). This led to a sharp decrease of levelised costs of electricity (LCOE) from PV and wind power, and tariffs for PV and wind power below 5 cents/kWh have been reached in many countries, for example in Mexico, Morocco, Peru, Spain, UAE Dubai and South Africa.[3] The LCOE of RETs and of wind and solar energy in particular are expected to decrease further during the next decade, leading to costs of about 5–6 cents/kWh on a global average (Table 1).

Table 1: LCOE estimates for solar and wind (2015 and 2025)

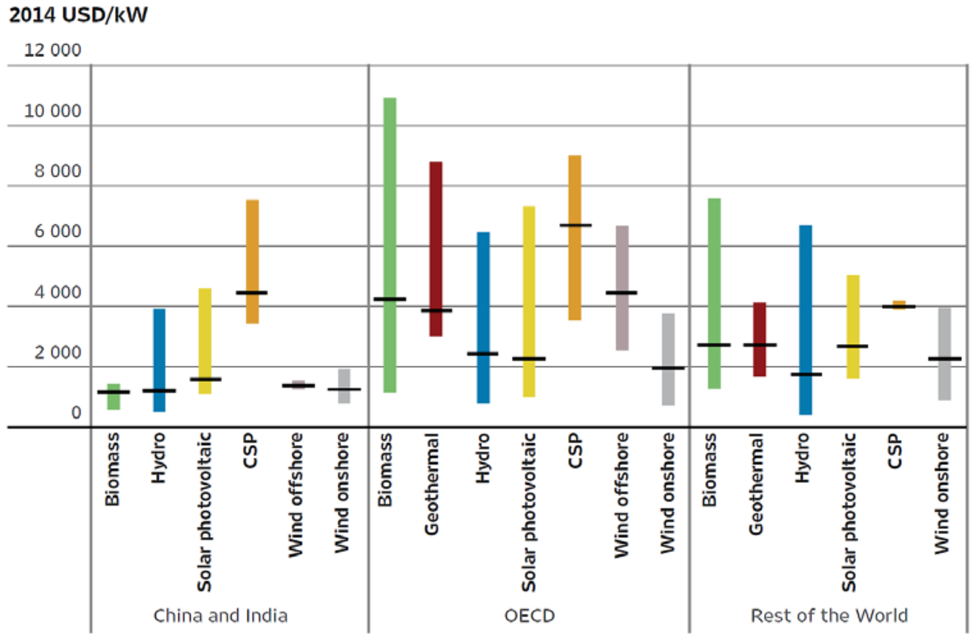
	Global weighted average data								
	Investment costs (2015 USD/kW)		Percent change	Capacity factor		Percent change[2]	LCOE (2015 USD/kWh)		Percent change
	2015	2025		2015	2025		2015	2025	
Solar PV	1 810	790	-57%	18%	19%	8%	0.13	0.06	-59%
CSP (PTC: parabolic trough collector)	5 550	3 700	-33%	41%	45%	8.4%	0.15 -0.19	0.09 -0.12	-37%
CSP (ST: solar tower)	5 700	3 600	-37%	46%	49%	7.6%	0.15 -0.19	0.08 -0.11	-43%
Onshore wind	1 560	1 370	-12%	27%	30%	11%	0.07	0.05	-26%
Offshore wind	4 650	3 950	-15%	43%	45%	4%	0.18	0.12	-35%

[3] LCOE is a common metric for the cost of electricity. It includes expected lifetime costs (financing, construction, fuel costs, maintenance, taxes, any support mechanisms and incentives). These are divided by the project's expected output over its lifetime. The results are adjusted for inflation and discounted. The use of LCOE as the primary method of comparing technology costs is controversial as the approach may unduly favour low capital cost technologies but high fuel costs over technologies with high capital costs but low or zero operating costs (such as many renewables). This can, for example, create a situation where investing in a small diesel generator may appear to be the most cost-effective option, despite the fact that it would expose the investor to volatile fuel costs in future. Other factors may favour renewables: for example, the LCOE approach does not include project risks, which may be higher with relatively new technologies such as renewables compared with conventional generation. There are also other limitations with LCOE, particularly the system implications of different generation types: on the one hand, projects with stable output may be more valuable to the system because output levels are predictable, while on the other hand, small-scale, intermittent renewables sited on distribution lines may have a value in reducing system losses, another factor which is not included in LCOE. The value of LCOE is only as useful as the data and assumptions used. Data on costs in SSA and SA are limited, so any projections should be treated with caution. While LCOE may be a useful way of comparing different technologies on the basis of certain assumptions, it is important to recognise that it does not present the whole picture.

IRENA (2016)

The most recent data on actual project costs published by IRENA provide an interesting insight into the different installed costs for utility-scale renewables projects at regional level. In some instances, the costs for renewable energy are lower in non-Organisation for Economic Co-operation and Development (OECD) countries than in OECD ones (see Figure 2). This may be because of previously untapped potential now being exploited in developing countries (e.g. for hydro projects) or because of better resources (e.g. for PV and Concentrated Solar Power (CSP)). The key point here is that the costs of grid-connected RETs may no longer be the barrier that they were a few years ago.

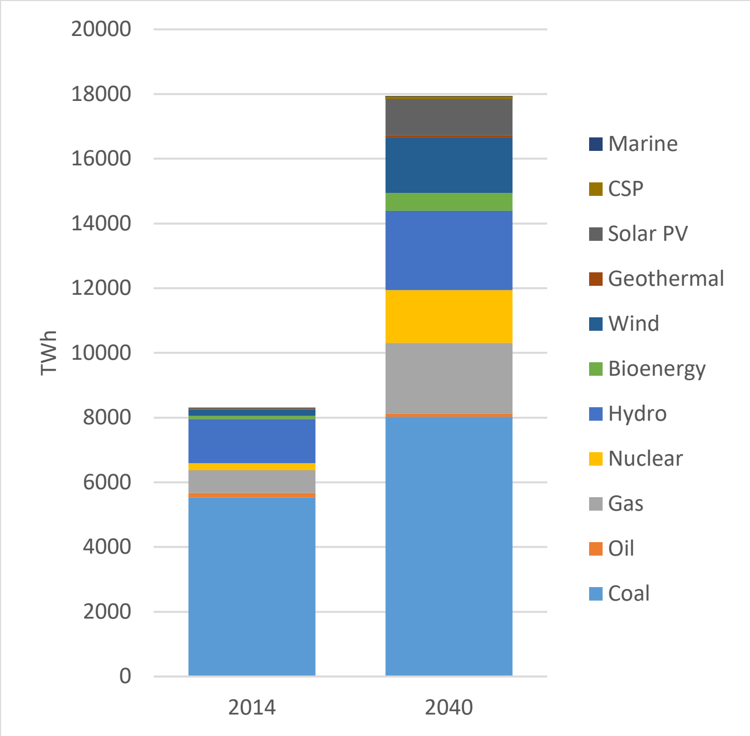
Figure 2: Typical Ranges and Weighted Averages for the total installed costs of utility-scale renewable power generation technologies by region, 2013/2014



IRENA (2015)

As a result, renewables appear to have an increasingly central role in the future provision of power in both SSA and SA, and while it is important to treat projections with some caution it is nevertheless worth outlining the current thinking about the role of renewables in the next few decades. The IEA's scenarios for world energy developments up to 2040 are set out in its annual World Energy Outlook (WEO). The baseline scenario, known as New Policies, includes the policy commitments made by countries together with a country's plans even if the actual measures to implement them have not yet been set out. The most recent WEO (IEA 2016c) projects that electricity generation will more than double in non-OECD Asia by 2040 and that, while coal will remain the largest single fuel source, renewables will provide just over one-third of generation (Figure 3).

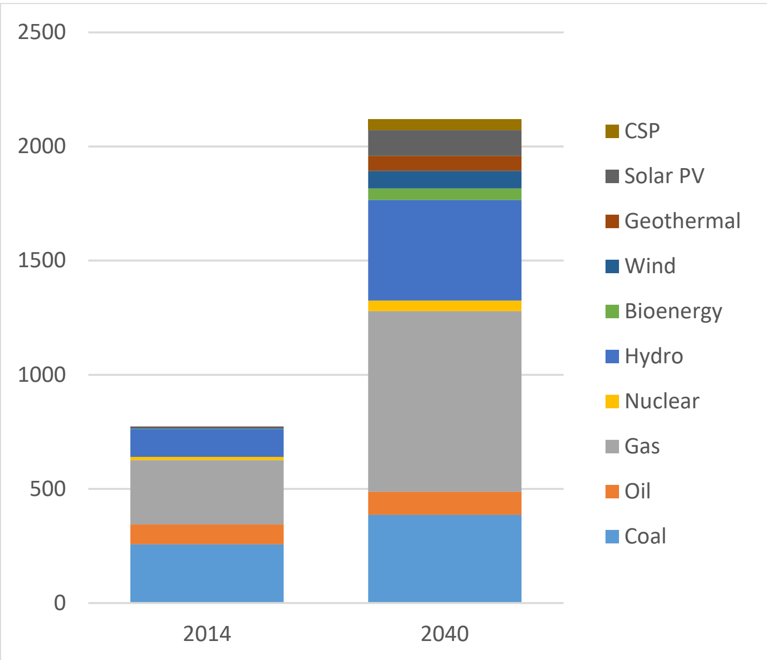
Figure 3: Electricity generation in non-OECD Asia (New Policies scenario)



IEA 2016c

The growth in generation is projected to be even more dramatic in Africa (Figure 4), with output tripling from 775 TWh in 2014 to 2,118 TWh in 2040. Renewables are projected to provide around 37% of total output. In both cases, hydro is expected to be the dominant source of generation but other renewable technologies, particularly wind and solar PV, also show a rapid increase in both regions. Other technologies, particularly CSP and geothermals, also make a growing contribution in Africa in particular.

Figure 4: Electricity generation in Africa (New Policies scenario)



IEA 2016c

Much of the growth is projected to provide power for industry in both regions. In non-OECD Asia, demand for electricity is expected to grow from 592 TWh to 1,313 TWh from 2014 to 2040, and in Africa demand is expected to triple from 52 TWh to 152 TWh in the same timeframe. However, despite the rapid growth in electricity generation in both regions, the goal of achieving universal access to energy by 2030 is not on track, with an estimated 619 million people without access to electricity in SSA in 2030, and 166 million in Developing Asia (IBRD *et al*. 2015). The IEA is clear that effective policies are fundamental to delivering an increase in access, and that decentralised, off-grid renewables are an increasingly viable way of expanding access (IEA 2016b). The role of policy and some of the major options currently in place are discussed in the next section.

The role of policy

Some countries have identified the renewables industry as a potential driver of economic growth, both domestically and through potential export opportunities. India, for example, has a well-established 'green' industrial policy articulated at federal level that has contributed to the growth of manufacturing and deployment of both wind and PV. Largely driven by the government's requirements for state-owned monopolies to implement RETs, India has seen impressive growth in renewables, with around 45GW of grid-connected non-large-scale hydro. Analysis suggests that this growth might have been even more impressive if it was not inhibited by a lack of coherent support for the manufacturing sector, a confusing policy environment and the poor financial position of state electricity utilities, which have combined to reduce the potential for renewables growth (Global Subsidies Initiative/International Institute for Sustainable Development (IISD) 2014), demonstrating that while 'command and control' policies can be effective, the enabling environment in which they are implemented also plays a significant role.

Kenya also has a well-established economy wide strategic vision, with a dramatic shift in the focus of its energy policy away from hydro over the last few years, and a medium- to long-term strategic economic development plan (known as the Kenya Vision 2030) that includes exploiting its extensive geothermal resources. The emphasis on geothermal power and other renewables is driven by a number of factors, including a desire to increase energy access, drive economic growth, reduce energy prices and fossil fuel imports, and diversify away from hydro to increase security in an area of uncertain rainfall patterns (Government of the Republic of Kenya 2007). As well as providing electricity, the geothermal projects in Kenya are producing broader learning benefits for other countries in the region, with the establishment of the Geothermal Energy Training and Research Institute at Dedan University (Mariita 2015).

On a more micro level, the rationale for policy support lies in the presence of market failures (the failure to cost environmental externalities) combined with the strategic value that may be associated with greater levels of renewables deployment, as well as the sometimes higher costs of new technologies, which create an argument for policy to encourage investment. A variety of policy mechanisms, regulatory instruments and planning tools are used reduce risk and the cost of capital for investors. This has contributed to the rapid decline in costs of some technologies due to learning effects and economies of scale, and the growth in renewables deployment has been driven in part by policies designed to give financial support and increased certainty to investors.

The most frequently used regulatory instruments in the power sector are feed-in tariffs (FITs) (often determined based on competitive bidding), (tradable) quota obligation systems, tax measures and investment incentives. Two of the most common support measures – FITs and auctions – are discussed below to highlight the degree to which the policy landscape for renewables is shifting as the technologies become more competitive.

FITs are generally well suited to achieving a high level of investment certainty by guaranteeing a fixed price for each unit of output for a sufficiently long but finite duration. They have proved successful in encouraging renewables in many instances. However, the success of FITs depends on the prices offered for output – too low and little if any new generation will come forward, too high and the costs of the mechanism may prove too high for consumers or taxpayers to bear. The risks of prices being 'wrong' can be mitigated by ensuring that there is flexibility within the mechanism to revise prices as a result of falling technology costs or inadequate rewards. This flexibility needs to be transparent and well signalled in order to avoid damaging investor confidence as a result of uncertainty about the stability of the mechanism. One of the key advantages of FITs is that they are relatively simple for both administrators and for project developers.

Another important aspect, which is closely related to the investment certainty offered by the support scheme, is its impact on innovation. The vast majority of the case studies conclude that FITs are more favourable for innovation because they allow for higher investment certainty and lower transaction costs. Both factors are particularly important for new entrants and for attracting external capital from financial institutions (Bürer and Wüstenhagen 2009) as well as private investors.

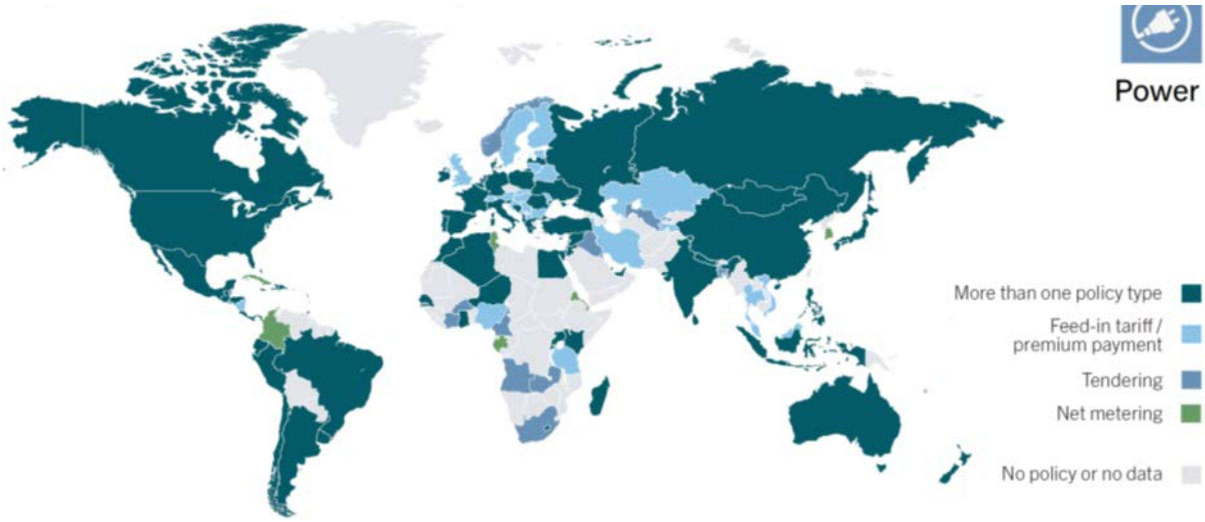
In recent years, auction-based FITs and feed-in premium systems have become increasingly popular as a means of encouraging reductions in the costs of support by exposing projects to a level of competition. The auction process typically involves the government inviting bids for contracts for different technologies for a specified number of years. Contracts are awarded to the projects offering output at the lowest prices depending on the different technology. This shift reflects the falling costs of technologies and a desire to encourage a degree of competition in bidding for contracts, so driving overall costs down. Refinements such as pre-qualification criteria and penalties for non-delivery of the project help ensure that developers avoid the 'winner's curse' of bidding too low to gain a contract and then discovering they are unable to deliver a viable project. Auctions are more complicated and risky than FITs given that they often require some up-front expense and project development without a guarantee of a contract being awarded.

Although auctions have led to low prices and reasonable realisation rates in a number of countries, it is too early to draw general conclusions on their performance especially with regard to effectiveness on RET capacity expansion and economic efficiency. As many of these auctions were introduced in recent years there is no comprehensive analysis yet on actual realisation rates, which were rather low in some cases in the past (e.g. the Non-Fossil Fuel Obligation during the 1990s in the UK). However, initial indications seem positive in terms of reducing remuneration rates. Auctions for onshore wind in Brazil and South Africa, and for PV in many word regions, including emerging and developing countries such as Brazil, India, Mexico, Peru, South Africa and Zambia, have proven successful in driving down costs. If this trend continues then auctions can be an important element to drive large-scale and low-cost expansion of renewable electricity in developing countries.

Auctions are yet to be widely implemented in SSA or SA. However, South Africa has attracted a great deal of attention following several rounds of auctions for renewables output (the Renewable Energy Independent Power Producer Procurement Programme) driven in part by a broader intention to expand private sector participation in generation. Prices for the contracts have fallen for all the technologies included in the auctions, in some cases dramatically: the price for wind power fell by 50% between the first and the fourth round of contract awards, to become comparable to the price of new coal generation (Department of Environmental Affairs 2015).

Countries in SSA and SA are increasingly adopting one or more specific policies to encourage renewables deployment (Figure 5). In practice, most countries will adopt more than one measure at national or subnational level to encourage the deployment of renewables (see Appendix 1 for more detail). As well as FITs and auctions, these other measures can include tradable green certificates for output, net metering to credit customers for any self-generation they export to the grid, and a range of fiscal incentives and public financing initiatives such as loans or grants for projects or outputs. In general, SSA and SA countries with higher incomes are likely to have more such measures in place that those countries classed as low income (REN21 2016).

Figure 5: Major renewable electricity policies in place (2015)



REN21 (2016)

However, the existence of a policy measure is not sufficient to ensure its success; the way that the policy is designed and implemented dictates whether it is effective at delivering its aims. There is a broad literature on evaluation criteria for promotional schemes and policy instruments in the fields of environmental economics and policy (Konidari *et al*. 2007, Mitchell *et al*. 2011). In general, these could be summarised as effectiveness in delivering greater levels of renewable deployment and/or other policy goals, and efficiency. Ideally, the efficiency should be both static (achieving the policy goal(s) at the lowest possible cost to society in the short to medium term) and dynamic (the measures achieve continuous reductions, for example through innovation in the medium to long term).

Achieving 'good policy' for technologies at different stages of development being deployed in markets with very different financial and operational arrangements implies that no one policy measure will be appropriate for all situations. Different policy measures are appropriate at different stages of a technology's or market's development (Kitzing 2014). So, for example, competitive auctions may be very successful in South Africa for wind and PV but may not be so suitable for technologies at an early stage of development or in countries with a relatively underdeveloped policy and regulatory structure.

However, the presence of financial support for a project is not the only factor influencing a decision to invest in renewables or any other generating technology. Support mechanisms can in part compensate for difficult conditions in the broader environment for projects, but they may be inadequate to overcome the full range of economic, political and institutional issues that can contribute to increased risk for investors. Addressing these factors to create a supportive ‘enabling environment’ implies a wider and more complex role for policy-makers and regulators intending to encourage increased levels of renewables deployment in their country. The range of different factors influencing individual investment decisions is discussed in the following section.

Factors influencing individual investment decisions

While electricity systems in developed countries have shifted toward liberalisation and the unbundling of vertically integrated utilities over the last 30 years, many utilities in developing countries remain as traditional publicly owned, vertically integrated, monopoly companies. Even where a degree of restructuring has taken place, the system is not yet fully liberalised but is instead operating as a sort of hybrid, possibly with some unbundling and Independent Power Producer (IPP) activity. More detail on this issue is given in the EEG State of Knowledge paper by Eberhard and Godinho, ‘A Review and Exploration of the Status, Context and Political Economy of Power Sector Reforms in Sub-Saharan Africa, South Asia and Latin America’.

The different system structures have implications for who might be investing in renewable technologies and why. In a system with a vertically integrated, monopoly utility, technology choices will be made by that utility, either with or without political direction (the ‘command and control’ model). The choice will tend to be dictated by company culture, political concerns about access or security, and the availability of finance, either off balance sheet or as a result of international donor programmes. Most countries with this structure have not invested significantly in non-large-scale hydro RETs to date, often because of the lack of available finance.

Having said that, many of the countries in SSA and SA have some degree of liberalisation in that IPPs are allowed to build and operate. Much recent research has focused on how to encourage more investment from these IPPs by ensuring that the ‘enabling environment’, made up of the wider economic, political and institutional conditions in any country, is sufficiently supportive to provide certainty about the return on an investment.

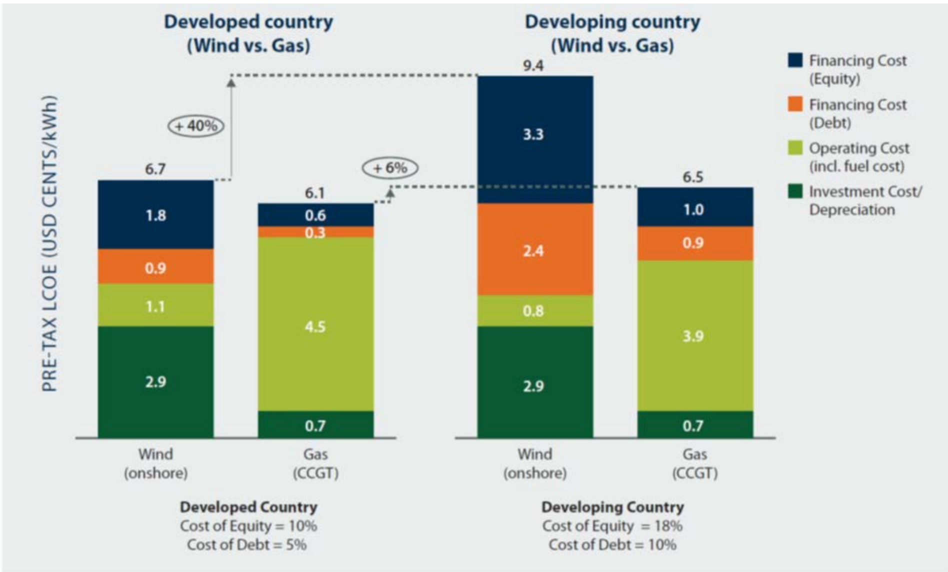
Encouraging independent investment in the electricity sector is considered important because many of the state-owned utilities are financially challenged, through poor collection of payments and/or underpricing of tariffs for electricity (e.g. Bangladesh, Nepal, Ghana and others). This has the dual impact of limiting their own investment plans as well as reducing their credibility as signatories to power purchase agreements (PPAs) with IPPs, so discouraging independent investment as well. This seems to be the case in Ghana, for example, where the distribution companies ECG and NEDCo are so heavily in debt that they cannot meet payment requirements for their current suppliers let alone new renewable projects (IRENA 2015a).

In the context of independent investment in electricity systems, investment results from a market participant´s individual decisions, which are based on their perceptions regarding the risks and profits of a given project. Understanding these determinants at both a country and project level is therefore pivotal for removing barriers and deploying policies to enhance an effective and efficient uptake of RETs.

At a country level, a large body of literature has addressed the conditions that are pertinent for the large-scale uptake of renewable energies in developing countries, including IPCC (2012), UNEP (2012), OECD (2007), Fischer *et al*. (2011) and Mani (2009). In general terms, the literature consistently outlines that, from an investor's perspective, developing countries and emerging economies are characterised by a higher real or perceived general market risk due to less stable political, legal and economic conditions for investments in larger-scale technologies. From a political perspective, unstable political regimes in general or a lack of stability concerning fiscal, energy or trade policies can represent a major risk component for any investor, particularly those engaged in long-term infrastructure projects. Regarding the legal component, general risks can materialise through the lack of ability to enforce private property rights (e.g. higher probability of expropriation or theft), a higher probability of violation of contracts, less probability of ensuring compensation payments if contractual obligations are violated, and civil disturbance or war. Finally, economic risks such as macroeconomic instability (impacting the volatility of the currency exchange rate, inflation, direct foreign investment, etc.) can represent substantial game changers for the business environment.

These risks are not unique to RETs, of course, and can affect conventional generation projects too. However, given that some renewables are less mature, less well understood by financial institutions and have different operating characteristics to conventional generation approaches, the impact of the perceived risks for RETs may be higher than for conventional generation (UNEP 2012a, World Bank 2013, Hamilton *et al*. 2016). The influence of this on financing and investment costs is illustrated by Wassbein *et al*. (2013) (Figure 6).

Figure 6: Impact of financing costs on wind and gas power generation costs



All assumptions besides the financing costs are kept constant between the developed and developing country.
For technology assumptions, see inputs for wind energy and gas (CCGT) in Section A.3 (Annex A); a 70%/30% debt/equity capital structure is assumed; financing costs are based on data in the four country case study (Chapter 3), assuming a non-investment grade developing country.
Operating costs appear as a lower contribution to LCOE in developing countries due to discounting effects from higher financing costs.

Source: Wassbein *et al*. (2013)

At a project level, Boie *et al*. (2015) present a synthesised conceptual framework based on a wide review of the literature of the main determinants for RETs' diffusion from the investor´s perspective (Figure 7). Each of these four main categories includes several sub-determinants, which characterise the conditions in each dimension. It should be emphasised that the framework presented by Boie *et al*. strictly refers to 'factors influencing' or 'main determinants' for RET development in general, therefore providing a neutral perspective on whether influential factors rather represent a driver or a barrier in a given context.

Figure 7: Main determinants for RET diffusion from the investors' perspective (adapted from Boie *et al.* 2015)

1) Economic and political framework	2) Electricity market structure and regulation	3) Grid infrastructure and grid regulation	4) Administrative procedures for RET projects
• Existence and reliability of RET strategy and support scheme • Relative remuneration level • Access to finance • Revenue risk	• Fair and independent regulation of the electricity sectors • Existence of functioning and non-discriminatory short-term markets • Availability of reliable long-term contracts (PPAs)	• Cost of RET grid access • Lead time for RET grid access • Predictability and transparency of grid connection procedure • Treatment of RET dispatch (curtailment) • Transparent and foreseeable grid development	• Cost of administrative procedure • Duration of administrative procedure • Complexity of administrative procedure

The following sections outline these determinants and their implications for the decisions of renewable energy investors. Many of the issues identified will be common to both public and private or donor investors. However, the degree to which they are significant may differ – for example, the public sector might be more willing to take on some project risks than the private or donor sectors.

Economic and policy framework

Existence and reliability of RET strategy and support scheme: Although the costs of renewable energy are falling, in many instances RETs remain more expensive than conventional fossil fuel generation at the utility scale (IPCC 2011). This shows the pivotal importance of the establishment of national targets and support schemes for the deployment of grid-connected RETs. As outlined by UNEP (2012), it is essential that project developers can trust that these incentives will remain in place over the lifetime of a project and that public institutions and the legal system are stable and can be relied upon.

Relative remuneration level: The relative remuneration level refers to the average remuneration level over the lifetime of the project considering the risk level and support scheme, as compared to the actual generation cost. In the context of developing countries, the actual remuneration level might be strongly affected by capital intensity, which tends to be higher for RETs than for fossil fuel-based generation projects. The cost structure of RET projects is characterised by high up-front capital expenditure (CAPEX) and low operating expenditure (OPEX) requirements, and, as with other electricity infrastructure, a long amortisation time (15–20 years or longer). The cost structure implies a high sensitivity to the cost of capital, which is significant larger in the comparably hostile investment environment in developing as compared to industrialised countries (in relative terms, with elevated political, economic and legal risks). This can be exacerbated by a lack of access to cheap finance.

Access to finance: Access to finance represents a significant economic framework condition for RET projects, in particular in countries with a poor track record on such projects. Financing institutions such as banks may lack experience with project risks, and will rather have a lower understanding of the project risks related to RETs and therefore less capability to evaluate the financing conditions. Additionally, project developers may also lack experience with RET-specific business and financial planning, including their awareness of funding opportunities. As a consequence, capital may need to be accessed at a higher cost. Lending to project developers in developing and emerging markets typically requires a higher proportion of equity relative to debt as compared to RETs projects in industrialised countries (IRENA 2012, Waissbein *et al*. 2013).

Revenue risk: In some case, as outlined above, renewable projects may be as cheap or cheaper than alternative investments. However, this grid parity depends in large part on the design and level of policy support for the projects, as well as the degree of certainty that gives to investors that they will receive a return. In other cases, renewables may be a more expensive option compared with conventional power technologies. In either instance, the revenues of RET projects are strongly determined by the supportive mechanism´s remuneration level. Any chosen support scheme (FITs, premiums and quotas) bears its own individual, design-specific risks (Boie *et al*. 2015). In addition to these inherent design risks, support schemes are put in place by policy-makers, thus leaving RET projects susceptible to political interference, representing a strong uncertainty factor in terms of the lack of real or expected stability of the RET support design or support level. This is likely to be the case in countries with higher political risks. Investors require long-term, consistent and credible energy policies (IRENA 2012). Revenue risk may also be exacerbated by the difficulties of raising tariffs for consumers in some developing countries, coupled with low rates of bill collection, meaning that utilities in those countries may not be financially credible.

Electricity market structure and regulation

Fair and independent regulation of the electricity sectors: With many developing countries and emerging economies being characterised by state-owned, fully vertically and horizontally integrated utilities, legislation and regulations can create unfavourable conditions for IPPs to enter the market. Fully integrated, state-owned, monopolistic utilities can be reluctant to enhance the participation of IPPs and, in some cases, a hostile state utility can act as a barrier to new entry, as recently seen in South Africa where Eskom is reportedly delaying signing contracts for renewables output arguing that the contracts are expensive and that the power is not needed, despite also pressing for the development of new nuclear facilities (Burkhardt and Cohen 2016, Fieldstone Africa 2016).

On the other hand, political direction for state-owned utilities to deploy more RETs has led to a rapid expansion in the sector in India, showing that if political will and finance exist then a ‘command and control’ approach to renewables can be effective.

Availability of reliable long-term contracts (PPAs): In addition to favourable legislation for the participation of IPPs, the possibility of accessible, transparent and reliable PPAs must be addressed by the overall policy framework. The duration of PPAs should be in line with the lifetime of RET projects (Boie *et al*. 2015). Following IRENA (2012), cases like in India have been reported where utilities have not been able to fulfil their contractual obligations as determined in the PPAs. In this context, UNEP (2012) also highlights the relevance of political risks, shown in the fact that large-scale RET projects (as opposed to micro- or off-grid projects) have publicly owned utilities as immediate counterparts within their PPAs, resulting in high vulnerability in terms of risks of political interference.

This is not just an issue for developing countries: developed countries can also experience shifts in the policy landscape. A recent report by Cambridge Economic Associates (2014) argued that the risk for IPPs associated with changes in the policy framework designed to support renewables might be lower in developing countries than in developed ones, given that most IPPs are contracted through PPAs. Unlike shifts in government policy, contracts can be enforced in the courts, so giving the IPP a level of protection. However, this argument assumes that the utility (or the state) has the resources to fulfil their contractual obligations in the first place.

Grid infrastructure and grid regulation

Predictability and transparency of grid connection procedure: Large-scale RET projects require access to the electricity grid with adequate capacity to inject the power generation into the system (Polzin *et al*. 2015). If adequate regulation is absent, grid connection might be a non-transparent, costly and time-consuming process. This matter can represent an accentuated barrier in developing countries with monopolistic, state-owned utilities, which lack experience of and legislation covering IPPs. Additionally, developing countries might have limited grid capacity and coverage, while lacking technical standards and certification as well as operation and maintenance facilities (IRENA 2012).

Cost of RET grid access: Accessing the grid might be costly. Boie *et al*. (2015) differentiate between deep cost charging (covering costs for connection and grid reinforcement), shallow cost charging (covering costs for connection to the nearest point) or super-shallow cost charging (no costs at all). In the absence of a track record of projects in many developing countries, cost uncertainties regarding grid access for investors and project developers might represent a substantial barrier to RET deployment.

Curtailment and grid development: The ability to connect to the grid and to export power are fundamental to the economics of large-scale renewable projects. However, infrastructure construction or reinforcement to accommodate new renewables projects can lag behind the speed at which RET projects can be deployed – transmission lines typically take several years to construct, compared with much shorter timescales for renewables. This can create a situation where renewable plants are ready to generate but have no connection available, or where projects are connected but are constrained off (curtailed) in the event that there is insufficient capacity on the distribution or transmission networks to accept their output.

Administrative procedures for RET projects

Cost of administrative procedure: Like every infrastructure project, large-scale RET projects face costly administrative procedures. Rules and regulations are in place to control safety, environmental impacts, health and quality controls, among others. Morisset and Lumenga-Neso (2002) present and analyse a database on 26 administrative procedures required for private investors to start and operate a business in 32 developing countries. The authors find administrative costs to be positively correlated with the level of corruption and strength of governance. Developing countries will thus generally face higher administrative costs than industrialised ones.

Duration of administrative procedure: Similarly, the duration of the administrative procedure might be significantly higher in developing countries. Morisset and Lumenga-Neso (2002) find that it might take two to three years to set up a business in a developing country. When grouping administrative procedures into 1) entry approval, 2) land and site development, and 3) operational requirements, the authors find the highest time delays in the second category, land and site development. From an investor´s perspective, time delays directly translate to costs (opportunity costs), which are evaluated before any investment decision. Especially for wind and to a lesser extent solar PV projects, delays in the administrative procedure can represent a substantial risk factor (Boie *et al*. 2015).

Complexity of administrative procedure: Finally, the complexity of the administrative procedure might itself represent a substantial barrier for the development of renewable energy projects, which might be aggravated by lack of clarity on requirements, lack of standardisation of procedures, lack of clarity of responsible authorities, number of different permitting authorities involved, etc. With the comparative lack of experience with RET projects in developing countries, higher levels of corruption and lower quality of governance, the complexity of administrative procedures is thus expected to represent a significant barrier.

Applying the conceptual framework to real-world experience

IRENA has produced a series of country-specific renewables readiness assessments (RRAs) outlining both the challenges and possible future developments for RETs in the countries covered.[4] The standard nature of the reports produced as part of the process allows a comparison to be drawn between countries. Using the RRAs, the reluctance to invest can be traced back to many of the key determinants identified earlier and relates to the range of political, regulatory and institutional factors set out in Figure 7.

The issues and recommendations in RRAs conducted to date in SSA are summarised in Table 3. It is clear that many key issues vary from country to country. It is also, however, evident that some factors inhibiting renewables deployment are consistently identified. For example, clear policy and strategy, a grid code that explicitly incorporates variable power and allows RET projects priority access, and streamlined permitting processes for IPPs are considered to be central requirements for renewables deployment in the short to medium term. It is clear from the RRAs that the focus of

[4] RRAs are a standardised tool for assessing the short- to medium-term actions considered necessary to encourage rapid renewables deployment and are reports intended to catalyse the process of developing a more supportive environment for renewable technologies in the short to medium term. An RRA is initiated and led by an individual country, and engages key sector stakeholders, implying a degree of political buy-in to the final report.

policy-makers in the countries studied needs to include more financial incentives for renewable generation and expand to include systemic issues such as grid operation and incentivising independent investment. However, it is also evident that there is no 'magic bullet' to create an enabling environment – the issues identified do differ from country to country, and effective policy responses will therefore differ too.

Table 3: RRA issues for grid-connected projects in SSA

Country	Economic and political framework	Electricity market structure and regulation	Grid infrastructure and grid regulation	Administrative procedures for RET projects	Other [1]
Mozambique (2012)	Need to clarify the legal aspects and timescale for introducing FITs to give certainty to IPPs	Uncertainty about revenue and financing is a barrier to IPP investment	EDM are undertaking grid expansion, which with short extensions could incorporate small hydro projects		Clarify the wind resource on the coast and in the highlands, and incorporate the infrastructure benefits from distributed generation
Senegal (2012)	Framework laws to encourage RET deployment exist but need to be implemented by decree. The laws include provision for support mechanisms (FITs)		SENELEC has no experience of integrating variable RETs into the grid		Some early experience of RET manufacturing that could be further exploited; limited understanding of resource availability and meteorological conditions
The Gambia (2013)	Draft Renewable Energy Bill awaiting adoption	Limited experience of negotiating PPAs		No renewables standards currently in place for design, quality, safety and Operations & Maintenance (O&M), lack of co-ordination of research and development (R&D) activity	Limited public education programmes or technical training programmes
Niger (2013)	Lack of engagement from IPPs in the absence of a national renewable energy action plan, support mechanisms and other institutional and regulatory frameworks	No specialised office in charge of negotiating PPAs			
Zambia (2013)	Policy currently emphasises hydro rather than the basket of RETs	Complex negotiations about PPAs increase transaction costs and limit investor certainty	The draft Grid Code needs to include an assessment of grid capability, including for variable power, and priority access for RETs		Limited knowledge of RETs' potential

Swaziland (2014)	SIPA does not grant investment and fiscal incentives to the renewables sector	PPAs are not standardised	The Grid Code does not provide for priority access; limited strategic identification of areas for cost-effective, high-potential and high-density RET projects		
Djibouti (2015)	No clear legislative and regulatory framework for electricity production, which limits the participation of IPPs. Electrification initiatives have focused on urban areas	Investment environment for RETs is weak	A master plan for generation and transmission is being developed, but the country currently has no energy policy and no road map for achieving large-scale RET-based generation		Limited domestic technical expertise and R&D
Ghana (2015)		Distribution companies are heavily in debt and not credible partners for PPAs	The Grid Code does not include generation forecasting for variable power and priority despatch for RETs	Procedures for negotiating PPAs are lengthy and complicated	

[1] These are other issues identified in the RRAs but related to more systemic issues rather than issues impacting on investors. They are included here for completeness.

Sources: IRENA 2012, 2012a, 2013, 2013a, 2013b, 2014a, 2015a, 2015b

Unfortunately, there is no set of equivalent studies that have been conducted on SA countries. However, it is clear from a range of studies of different SA countries that many of the experiences are common between the two regions, with similar impacts on investor perceptions of risk (Asian Development Bank 2015, UNEP 2012).

Measures to encourage the deployment of RETs

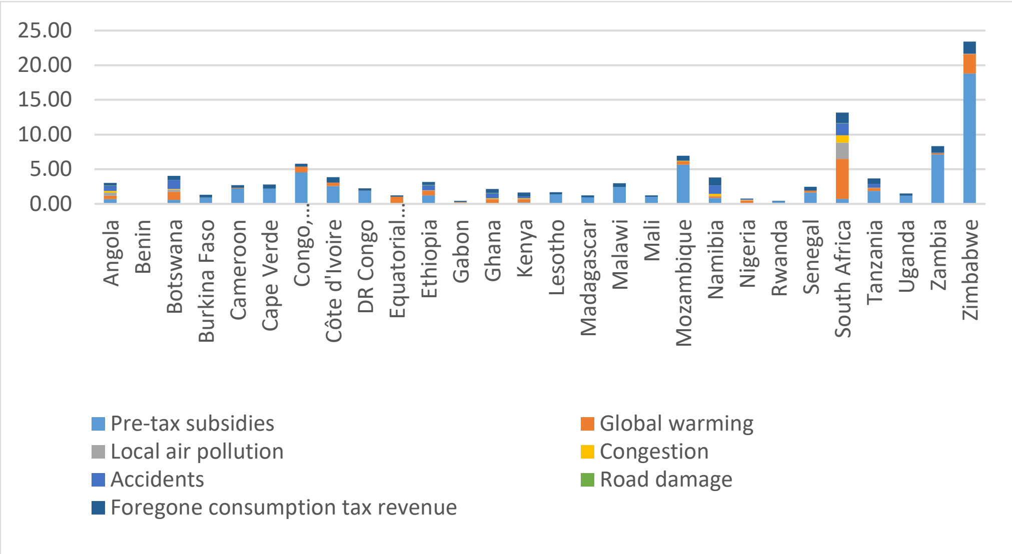
Policy-makers and regulators have a central role in creating an ‘enabling environment’ for renewables deployment, by ensuring that economic, political and institutional conditions are supportive of the technologies, and of investors. This can be achieved by removing barriers to deployment, and also by putting in place measures that would support increased levels of renewables deployment and generation. This section discusses some of the complexities involved in making policy for future electricity system development, followed by some suggestions about how barriers might be removed and a more enabling environment created.

Levelling the playing field

Fossil fuel subsidies can impact on renewables investment in several ways. They can limit the cost competitiveness of renewable energy as an option by artificially lowering the prices of fossil fuel inputs, or electricity generated using fossil fuels. Subsidies can also have an impact at a systemic level; for example, providing subsidies to fossil fuels can reduce the funding available for infrastructure such as the grid, which might support renewables deployment (IISD 2014).

The International Monetary Fund (IMF) estimates that global energy subsidies in 2015 amounted to about US$ 5.3 trillion, or around 6.5% of global GDP.[5] Much of this subsidy is related to environmental externalities, particularly global warming and local air pollution. The IMF's database shows a wide disparity between the level of subsidy in different countries, and how they provide these subsidies, both in the nature of the subsidy and the product subsidised (see figures 8–11 below). Unfortunately, the report does not differentiate between fossil fuel and renewables subsidies, although the evaluation of policy measures to promote renewables in the IMF's data implies that the majority of the subsidies given to the electricity sector are dominated by fossil fuel (see also IISD 2011). In addition, it is worth bearing in mind that a proportion of the subsidy given to other fuels will ultimately translate into an electricity subsidy.

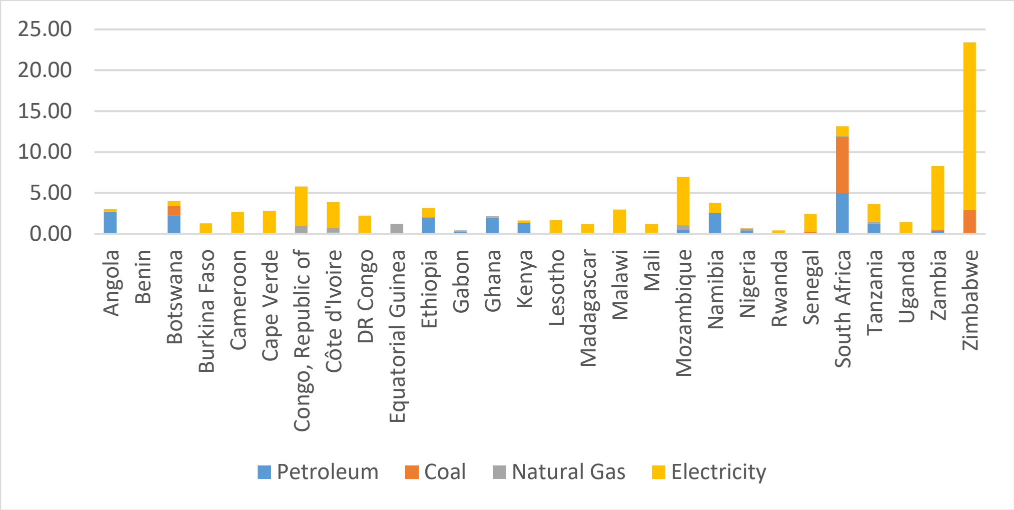
Figure 8: Post-tax subsidies as % of GDP in SSA



IMF (2015a)

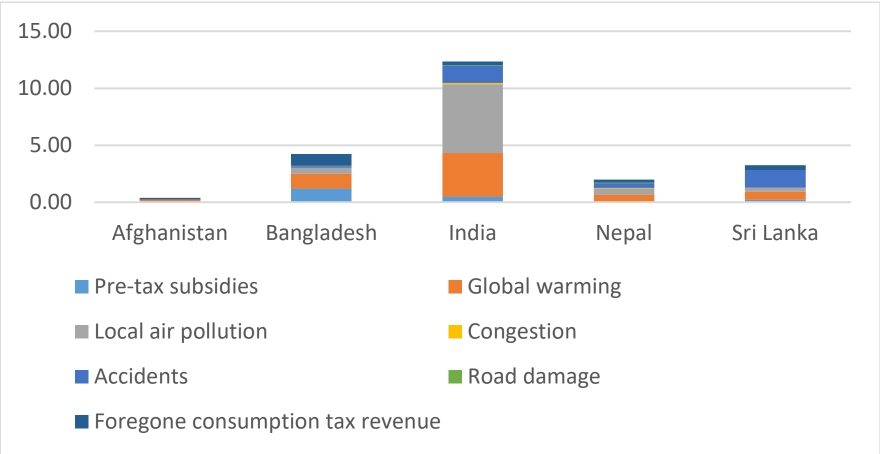
Figure 9: Post-tax subsidies as % of GDP by product in SSA

5 The issue of subsidies, particularly for fossil fuels, is complex and controversial, in part because definitions of what constitutes a subsidy vary (see IEA 2006, UNEP 2008, Burniaux *et al*. 2009, Ellis 2010, IISD 2011). For simplicity, this paper has used the recent IMF study (IMF 2015) as a source, in part because it is supported by a relatively complete country-level breakdown by product and by criterion, which includes SSA countries and most of those in SA. In addition, the report is explicit about the problems of estimating subsidies, and the degree of caution that must be adopted when considering the results.



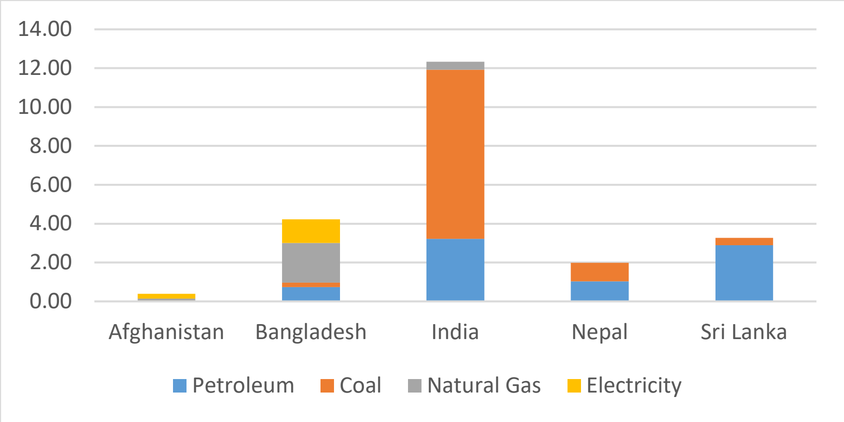
IMF (2015a)

Figure 10: Post-tax subsidies as % of GDP in SA (2015)



IMF (2015a). No data for Bhutan, Maldives and Pakistan

Figure 11: Post-tax subsidies as % of GDP by product in SA



IMF (2015a). No data for Bhutan, Maldives and Pakistan

There are two complementary and interrelated fiscal approaches that could be adopted to level the playing field between renewables and fossil fuels. The first would be to remove or reform subsidy regimes that favour fossil fuels. The second would be to ensure that the environmental externalities associated with electricity production are reflected in prices. To date, these approaches tend to be adopted in conjunction with policy mechanisms to promote renewables.

The failure of the market to price environmental externalities is a key part of any debate about energy pricing and subsidies. A variety of mechanisms exist, either in practice or in theory, to address this, and include carbon taxes and carbon-trading schemes. Both approaches could encourage investment in renewables but will require a realistically high price to be set on carbon in order to be effective. Carbon tax systems have not been widely implemented in SSA and SA, but do have some potentially attractive characteristics, not least the possibility of recycling the revenues raised toward development and access programmes as well as other social programmes or efforts to encourage more renewables investment.

A more complex approach would be to implement a carbon-trading scheme, either on a national or regional level. The economic argument behind carbon-trading schemes is elegant, but the efficacy of any scheme is dependent on a variety of variables, in particular political commitment to setting realistic emissions limits and reasonably high carbon prices[6] (Jenkins 2014). An emissions-trading scheme is also more complex to organise and monitor than a straightforward tax. At the moment, no country in SSA or SA is directly involved in emissions-trading schemes, although they may be involved indirectly through Clean Development Mechanism projects (International Carbon Action Partnership 2016).

Capacity in policy-making and governance

Renewables can contribute to realising the broad goals of energy security, environmental performance and economic activity outlined earlier, but it is important that this is done in a way that also mitigates or avoids the potential detrimental effects they could cause. This in turn requires

[6] The experience of the EU Emissions Trading Scheme has shown that low fossil fuel prices, and undemanding emissions limits in the early phases, failed to produce sufficient long-term signals to drive investment in renewables because there was an excess of permits and the cost of buying them was therefore very low.

policy-makers to develop a balanced energy policy with an explicit recognition that there may have to be trade-offs between the different drivers, for example between delivering greater security while avoiding environmental impacts, or enhancing access rather than realising the economic benefits of exporting power.

The case of large-scale hydro developments demonstrates some of the trade-offs between the three drivers of enhanced security, environmental performance and economic activity. On the one hand, hydro power can provide storage capacity to compensate for the variability of other RETs, but the resource is dependent on seasonal rainfall and in dry periods the security benefits of hydro may be limited. For example, load shedding occurs for up to 14 hours a day in grid-covered areas in Nepal in the dry season (World Bank 2016), while uncertain rainfall patterns have caused power shortages in other countries such as Ghana and Kenya. The impact of this might be mitigated to an extent by developing more hydro resources in the country or the region, but the risk of reduced river levels remains.

Hydro power provides most of DRC’s electricity generation, largely from the Inga River I and II projects. The planned Inga III project in DRC could ultimately make up part of the world’s largest hydro complex, known as Grand Inga and with a capacity of around 4 GW. One of the primary roles of Inga III would be to export electricity across Africa, with over half of Inga III’s 4.8GW output destined for South Africa (International Hydropower Association 2015). A further 1.3GW would be sold to the mining industry in the south of the country, leaving around 1GW for the state-owned utility SNEL. Given the current low electrification rate in DRC (9% overall), this exceeds current demand in the country, but the plan also reveals the trade-offs inherent in developing such a large project, realising commercial and economic opportunities in SSA but without having the infrastructure in place to fully exploit the resource in the short term at a domestic level.[7]

Governance for some policy issues may also have to evolve at a multinational level, implying that policy-makers will need strategic capabilities at the international level. This is particularly the case for hydro power, where river resources can cross national boundaries and the trade-offs take on a geopolitical dimension. Taken together, India, Pakistan, Nepal and Bhutan are currently proposing around 400 hydro dams around the Himalayas, which could provide around 160GW of electricity. In addition, China is proposing a similar level of generation from Tibetan rivers, meaning that the Himalayas could become the most dammed region in the world (Grumbine and Pandit 2013). While the outcome would be low carbon electricity, if all the projects proceed there would also be significant environmental impacts, population displacement and the prospect of growing regional tension over water resources.

Balancing these issues may require a level of policy expertise and experience that is not always available. This can include an awareness of the renewable resources available, the ability to assess and evaluate the security, environmental and economic impacts of pursing different options, and the willingness to make those trade-offs apparent. In other words, institutional capabilities are a key component of good governance for RETs’ deployment.

Possible ways forward

[7] In September 2016, the World Bank suspended its support of the Inga III projects as a result of the DRC Government taking the project in a ‘different strategic direction to that agreed between the World Bank and the Government in 2014’. The Bank did not specify what the strategic changes were.

As outlined in earlier sections, there are some very clear messages about the desirability of stable regulatory and support schemes as a means of reducing investment risk (whether in the public or private sector). However, there are also lessons about access to the grid to enable the projects to operate effectively, and also about market design – both of which impact on project finances. Much of the research to date has focused on designing effective policies to encourage early deployment of RETs and compensating for hostile conditions in the broader environment (Wassbein *et al.* 2012, IPCC 2012, IRENA 2012, Frankfurt School *et al.* 2016). Overall, much of the effort in renewables has been directed at increasing capacity in the short term, reflecting the short-term need to expand electricity systems in developing countries.

However, as renewables become more widely deployed and economies of scale and learning effects are experienced, it is likely that technology costs will continue to fall and they will become more competitive options. The key question then is how to maximise the impact of this by developing stable revenue conditions to minimise financing costs and by ensuring that the system overall is optimised to accommodate increasing levels of renewables generation. In effect, this means extending the idea of an enabling environment from a technology-focused approach to something more systemic. This understanding has recently become a component of many of the more strategic, forward-looking information published by the IEA in particular (IEA 2008, IEA 2014, IEA 2016a, IEA 2016b, Lund *et al*. 2015).

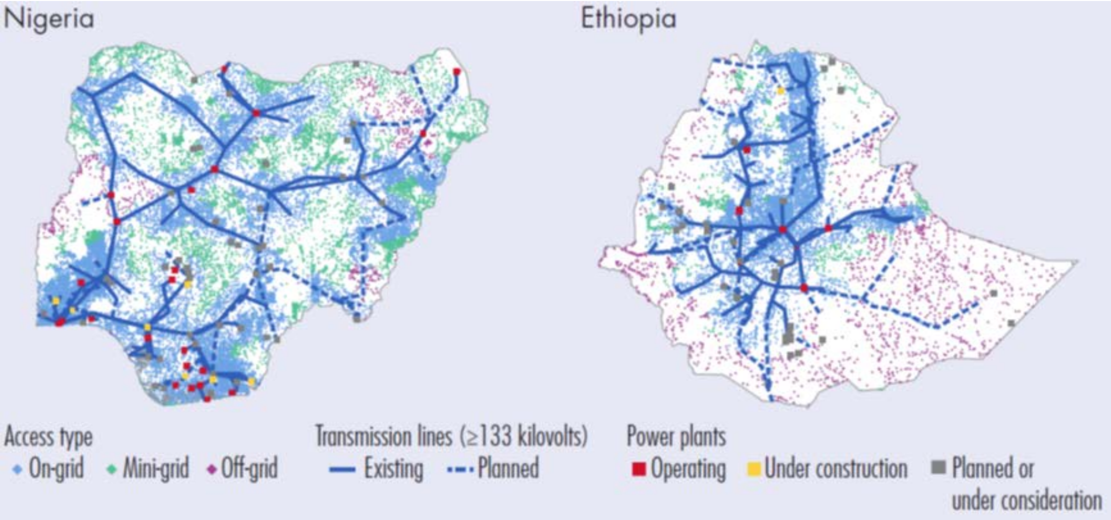
Some renewable technologies (hydro, biomass and geothermal) can provide constant – or at least predictable – output in the same way as thermal generation, and therefore fit with the 'conventional' pattern of electricity system operation. However, the technologies where the most dramatic cost reductions are being witnessed are variable and often smaller scale than more conventional options. These characteristics have significant implications for the future development and operation of electricity systems. This section considers some of these implications, and how the challenges raised by increasing levels of variable operation might be addressed in expanding electricity systems.

Electricity systems with high shares of variable renewable energy (VRE) technologies like wind and PV tend to deviate from the traditional structure consisting of central generation units combined with unidirectional transmission and distribution of electricity and supply following demand. Instead, these systems are characterised by bidirectional flow patterns on both transmission and distribution networks, as well as variable output that needs to be balanced across the system. This requires increased flexibility on both the demand and supply sides, more active system management and, in places with high renewables deployment, it can also require grid strengthening (Cochran 2014, IEA 2005, IEA 2008, IEA 2014, IEA 2016).

The issue of how 'best' to develop electricity systems needs to be approached in a strategic way. For example, some key questions need to be addressed in order to understand the degree to which large-scale renewables might be appropriate as a means of increasing access, and some substantial challenges need to be overcome in particular with respect to supplying consumers in rural areas, which go beyond the general concepts for electricity market design and renewable remuneration schemes. In particular, it will be important to understand the 'right' mix of large-scale, grid-connected electrification vs. small or off-grid, renewable devices in countries with low electrification rates and what benefits off-grid decentralised renewable generation might provide compared to large-scale installations.

Utility-scale renewables could offer some economies of scale compared with micro and off-grid solutions, but they would also entail the need for expensive network infrastructure to be built. In the short term at least, this might not be financially feasible for all developing countries, and even if the finances were available, the costs involved would largely have to be passed on to consumers or taxpayers, so potentially reducing their ability to access electricity services. In some cases, large-scale renewables might not be the most effective or efficient option: the economics of grid expansion depend on an individual country's population density, the tariffs for grid-provided electricity, technology costs and fuel costs (especially diesel), as well as the macroeconomic situation in that country. So, for example, the Sustainable Energy for All initiative shows very different optimal grid expansion patterns for Nigeria and Ethiopia, reflecting the countries' differing demographic and socio-economic conditions (Figure 12; IBRD *et al*. 2015).

Figure 12: Optimal split by grid type in Nigeria and Ethiopia, based on anticipated expansion of main transmission lines



IBRD *et al*. 2015

The impact of widespread VRE deployment on networks and markets is already being seen in some developed countries, which are beginning to experience issues such as transmission congestion, the need to export at peak generation times, and market prices that are dependent on renewable resource availability on a given day (e.g. Germany and Denmark). Policy-makers, regulators and system operators are beginning to address these issues by introducing measures such as demand management techniques (not just load shedding) and electricity storage, more flexible network design, and innovative pricing policies.

The level of VRE deployment in most developing countries has not yet reached the level where the impacts are significant. However, India is an exception, and it is reported that grid connection issues mean that solar plants in the south are being curtailed as there is no way to export the power to areas of demand (Manley 2016). The problem is also acute for wind in Tamil Nadu, where peak wind generation occurs between June and September. At that time, there is about 1GW surplus power in the state but insufficient infrastructure to export it to other states. This has increased calls for an inter-state Green Energy Corridor to be built to accommodate the renewables output from the south by providing additional transmission capacity for renewables in the south and strengthened connectivity with other regional grids. This enlarged transmission area should provide a larger area across which the output from variable renewables can be balanced (Asian Development Bank 2015a).

Integrating large shares of VRE cost-effectively calls for a system-wide transformation and for policy-makers to create the enabling environment in which this can take place. Factors which can improve the 'system friendliness' of renewables project siting include (IEA 2016, 2016a):

- Ensuring a mixture of technologies and locations is used to benefit from complementary resources and reduce temporal correlations of generation;
- Power plant design, such as the use of wind turbines that are optimised for higher generation during periods of lower wind speeds; and
- Using modern wind turbines and PV systems that can provide a wide range of technical services needed to maintain short-term grid stability.

In addition, various market measures will be required in order to reflect the greater levels of VRE expected to be deployed. These include improving short-term power markets to allow buying and selling to take place closer to real time to accommodate fluctuations in output, coordinating system balancing over larger areas to smooth local fluctuations, and the development of market arrangements that put a value on technologies or measures enhancing the flexibility of the system (for example, consumers being rewarded for temporarily reducing demand at times of high system demand or low VRE output). Other measures to build markets around the characteristics of VREs include the use of storage, hydro power or electrical storage in new battery technologies, and the use of capacity mechanisms to provide financial rewards to non-renewable generators whose output might only be required when demand is at its peak.

As more VREs are deployed, the issues will become more acute in other electricity systems. This is a particularly significant issue for developing countries' electricity systems – i.e. those that are expanding – as there is an opportunity to develop the necessary infrastructure and market arrangements from scratch, rather than adapting existing infrastructure to accommodate new technologies.

Designing these measures into expanding electricity systems and markets will create very different systems compared to those in most developed countries, which has been recognised by the Africa Progress Panel. Expanding electricity systems in developing countries have the opportunity to 'leapfrog' the issues currently being faced by established systems as they try to shift to more sustainable models by adjusting the factors at the regime level that act as disincentives to deploying more renewables. Focusing on the drivers and barriers to increased renewables capacity will provide useful information and lessons that can be disseminated between policy-makers. However, if renewables are to become a normalised investment option for developing countries then a broader, system-based approach will be needed to create an enabling environment for infrastructure and governance to allow electricity system development to progress along more sustainable lines. This includes the need for a longer-term vision about system development and operation to reflect the incorporation of greater levels of renewable generation.

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Appendix 1: Renewable energy and electricity targets, policy measures and incentives in place in SSA and SA 2015

	Targets		Regulatory policies							Fiscal incentives and public financing					
	Renewable energy target	Renewable electricity target (overall share, capacity or generation)	FIT/premium payment	Electricity utility quota obligation/Renewable portfolio standards	Net metering/net billing	Transport obligation/mandate	Heat/cooling obligation/mandate	Tradable Renewable energy certificate	Tendering/auction	Capital subsidy, grant or rebate	Investment or production tax credit	Reduction in sales, energy, VAT or other taxes	Energy production payment	Public investment, loans or grants
SUB-SAHARAN AFRICA														
ANGOLA	□	□												
BENIN	□	○												
BOTSWANA	○	□								○		○		
BURKINA FASO									○		○	○	○	
BURUNDI		○												
CAMEROON												○		
CAPE VERDE	○	○			○				○		○		○	
CENTRAL AFRICAN REPUBLIC														
CHAD														
COMOROS	○	○												
CONGO (BRAZZAVILLE)														
CONGO (DRC)	○	○												
CÔTE D'IVOIRE	○	○												
DJIBOUTI	○	○												
EQUATORIAL GUINEA	□	□												
ERITREA		○												
ETHIOPIA	○	○	□											
GABON	○	○												

THE GAMBIA	○	○										○		
GHANA	○	○	○	○	○	○		○		○		○		○
GUINEA	○	○										○		
GUINEA-BISSAU	○	○												
KENYA	○	○	○		○		○		○			○	○	○
LESOTHO	○	○			○				○	○	○		○	○
LIBERIA	○	○										○		
MADAGASCAR	○	○												
MALAWI	○	○				○						○		○
MALI	○	○				○						○		○
MAURITANIA	□	□												
MAURITIUS	□	○												
MOZAMBIQUE		○				○						○		○
NAMIBIA		○												
NIGER	○										○			
NIGERIA	○		○			○				○		○		○
RÉUNION														
RWANDA	○	○	○						○		○	○		○
SAO TOME AND PRINCIPE		○												
SENEGAL	○	○	○	○	○				○			○		
SEYCHELLES	○	○			○						○	○		○
SIERRA LEONE		○												
SOMALIA														
SOUTH AFRICA	○	○		○		○	○		○	○		○		○
SUDAN	○					○								
SWAZILAND														
TANZANIA	○	○								○		○	○	○
TOGO	○											○		
UGANDA	○	○	○						○	○		○		○
WESTERN SAHARA														
ZAMBIA										○		○		○
ZIMBABWE	○					○						○		○
	□													
SOUTH ASIA														

AFGHANISTAN														
BANGLADESH	○	○							○	○		○		○
BHUTAN		○												
MALDIVES	○	○							○					
NEPAL	○	○						○	○	○	○	○		○
INDIA	○	○	○	○	○	○	●	○	○	○	○	○	○	○
PAKISTAN	○	○			○	○		○		●		○		○
SRI LANKA	○	○	○	○	○	○				○		○	○	○

Key:		**Sources:**
○	National or subnational target	REN21 Global Status Report 2016
●	Subnational target only	Tables 4, R16, R17, R18, R19