United Nations
Framework Convention on
Climate Change

TEC Brief #8

Technology Executive Committee

Facilitating Technology Deployment in Distributed Renewable Electricity Generation

Photo: "Garvins Hydro Dam", Courtesy Eversource Energy and Bob Gundersen

Why this TEC Brief?

Distributed small-scale electricity generation from renewable energy sources (distributed renewable electricity generation) has emerged as a technically and financially viable alternative to electricity production from fossil fuels. Distributed renewable electricity generation offers significant promise as a route for decarbonization of the electricity sector, and can help towards achieving the objective of keeping the increase of global average temperature below 2 °C. Distributed renewable electricity generation also enables increased energy access by providing rural electrification and satisfying demand growth.

The increase in the deployment of distributed renewable electricity generation technologies is also changing a century-old paradigm of centrally located facilities producing electricity and sending it to consumers through a transmission and distribution network.

This TEC Brief is intended for policymakers and other stakeholders, and provides an overview of distributed renewable electricity generation technologies and offers policy options that can facilitate their deployment and absorption.

Highlights

- Distributed renewable electricity generation can contribute significantly to the reduction of greenhouse gas (GHG) emissions through the generation of low-carbon electricity.

- It can deliver electricity services in areas that cannot be supplied by centralized grids and also provide co-benefits to communities, such as enhanced energy security, reduced local air pollution and reduced dependence on imported fossil fuels.

- It can provide additional sources of electricity in grid-connected systems, thus enhancing the energy security, resilience and efficiency of such grids.

- For distributed renewable electricity generation technologies to reach widespread use, the following actions and measures are needed:
  - Build and strengthen in-country capacity in the form of human and institutional capabilities, including through national systems of innovation, in order to fully enable countries to develop, transfer, deploy and operate nationally distributed renewable electricity generation systems. More assistance and technology improvement may be needed to enable systems to cope with intermittency in a cost-effective manner;
  - Develop or update and implement transparent, effective policy and regulatory frameworks that promote distributed renewable electricity generation, as appropriate;
  - Stimulate robust private-sector involvement and investment through appropriate incentives, and facilitate the implementation of effective and proven business models;
  - Ensure the active participation of, and effective collaboration between, all stakeholders.

Photo: ”Bangi Bay Windmills” by Perry A. Dominguez is licensed under CC-BY-SA-3.0

1 Concepts and Definitions

Most electricity worldwide is produced at large power plants (1–1,000 MW) and delivered to electricity users through transmission and distribution networks. This is called 'centralized' electricity generation. There is, however, another approach: the use of smaller power systems, with a capacity of up to 1 MW, located at or near electricity users.[1] This is known as a 'decentralized' or 'distributed' electricity generation.

Distributed electricity generation has advantages compared to traditional, centralized generation; however, the centralized model also has some advantages (see table 1). For example, in rural areas without electricity services, distributed generation in off-grid or mini-grid systems may be the only practical option because the costs of extending the centralized grid may be prohibitive. In areas where a centralized grid is already installed, adding distributed electricity generation increases the diversity of supply and can improve system resilience and enhance energy security.

In terms of definition, a common – but by no means universal – use of the term 'distributed' is to refer to electricity generation technology with a rated capacity of 1 MW or less. The technologies themselves are typically described or defined by a range of terms, including 'commercial', 'micro' and 'household' (see figure 1).

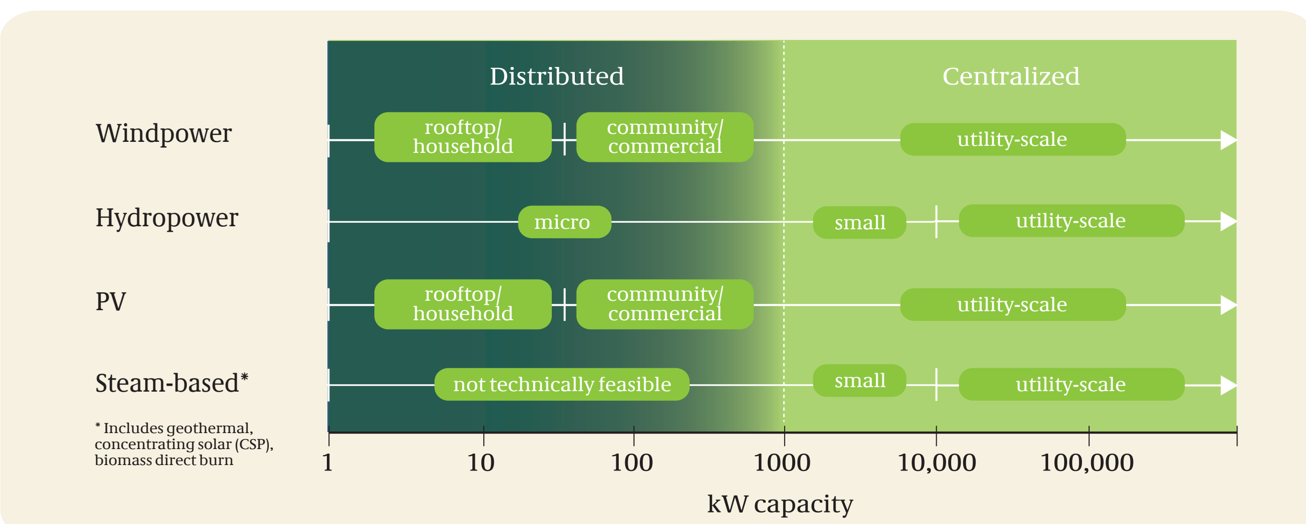
For 'distributed grids', there are other terms often encountered in relation to such technologies:

Table 1: Comparison of centralized and distributed electricity generation and grid

Model		Advantages
Centralized	Generation	- Wide range of mature technologies - Lower per-kW costs
	Grid	- Higher load diversity->flatter demand profile - Well-developed industry
Distributed	Generation	- Allows for direct and local private investment - Increased diversity of supply, greater system resilience and enhanced energy security
	Grid	- Applicable to small/remote communities and urban areas - Reduced transmission and distribution losses

- **Off-grid.** This typically refers to a single structure that provides its own electricity and is not connected to any other electricity users.
- **Nano-, micro- and mini-grids.** These are electricity grids that typically serve from one to thousands of electricity users. In general, *nano* refers to grids serving one to tens of users, *micro* refers to grids serving tens to hundreds and *mini* refers to grids serving hundreds to thousands. These smaller grids can also be connected to larger, centralized grids.

Figure 1: Scale of renewable electricity generation technologies



[1] To put this into context, a typical residence in a developed country needs about 1 kW. However, much smaller systems, down to 10 W, are also very common, such as for lighting.

2 Distributed Renewable Electricity Generation Technologies

There are several technologies that can provide renewable electricity at a distributed level. Table 2 outlines the most common ones.

Distributed renewable electricity generation technologies have their own specific characteristics, which have to be taken into account to ensure appropriate deployment. These characteristics include: modular design, high up-front costs but low operating costs, and resource-dependent production profiles.

A major constraint for some distributed renewable electricity generation technologies, such as wind turbines and photovoltaics (PV), is the variability of output. When they supply a modest fraction of the total electricity, their variability can be managed by the use of various techniques such as ramping of dispatchable renewable electricity generation (as in hydropower or biomass plants) and demand side management, especially in distributed grids. Estimation methodologies to set energy efficiency criteria can help to reduce excessive demand peaks

Table 2: Comparison of common distributed renewable electricity generation technologies

Technology	Typical capital cost (USD/kW)*	Resource or fuel needs	Operation and maintenance needs	Variability of output – diurnal**
Photovoltaic system	2–5	Sunlight	Low	High
Micro hydropower	3.4–10+	Consistent water flows	Medium	Low
Small wind turbine	7	Wind > 3 m/s	Medium	***

* For sources, see Komor and Molnar (2015). These costs do not include storage.
** Other time scales may also be of interest, notably annual and 'climatic' (longer term). For these time scales, variability may vary by location. For example, photovoltaic output will vary considerably over the course of a year for installations at greater latitudes, but much less so for installations near the Equator.
*** Depends on specific location. Some regions show large day/night variability in the wind resource, others much less so.

Photo: "Solar panel on straw-hut roof" by cotrim is licensed under CC0 1.0

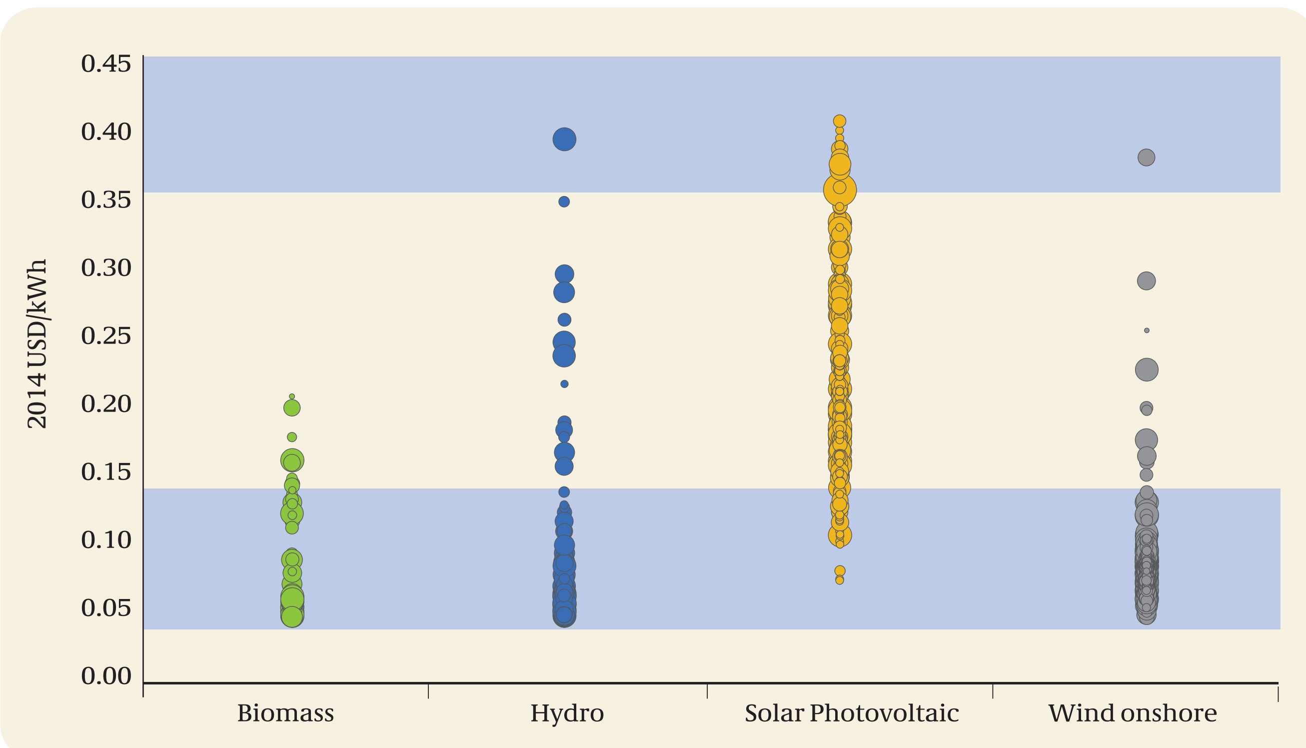
during operation. Technologies such as smart grids can also increase grid efficiency. For distributed grids without dispatchable generation, storage is required, which poses economic and technical challenges.

In terms of costs, those of PV systems have dropped significantly recently – halving between 2010 and 2014 alone (IEA, 2014; IRENA, 2015a) – creating focus on this technology and increasing its cost-competitiveness. As prices fall, PV systems may eventually reach socket parity (i.e. cost-competitive with retail electricity) and even grid parity (i.e. cost-competitive with wholesale electricity). As solar PV module prices decrease further, the number of markets where solar PV systems is competitive will continue to grow.

In some instances, distributed renewable electricity generation can be very cost-competitive, even with wholesale electricity generation costs (see figure 2). However, the smaller projects cannot achieve these levels of competiveness, and small-scale PV systems with storage can have delivered electricity costs as high as 2014 USD 0.65/kWh. However, in remote areas, this can still be a cheaper and more reliable solution than diesel-fired power generation (IRENA, 2015b).

Technology needs assessments conducted by developing countries in the last years indicate that renewable electricity generation technologies have been prioritized by many countries, with PV systems being the most prioritized for the energy industry subsector (UNFCCC, 2013). Out of these, more than 20 per cent of the total number of prioritized technologies for electricity generation consisted of small-scale technologies.

Figure 2: Cost data on renewable and non-renewable electricity generation



Notes: The blue shaded upper and lower ranges illustrate the costs of distributed diesel-fired electricity generation and utility-scale fossil fuel-fired electricity generation, respectively. Biomass power generation projects will be mostly cogeneration, and photovoltaic data exclude projects with battery storage.
Source: International Renewable Energy Agency Renewable Cost Database.

3 Perspectives of Stakeholders and Barriers

The specific characteristics of distributed renewable electricity generation technologies require a wide range of stakeholders – from electric utilities to financiers to regulators to end users – to pro-actively engage in the production and provision of electricity. It is therefore critical to understand and respond to stakeholders' perspectives on and concerns with these technologies (see table 3).

Case studies can provide valuable information and lessons learned on barriers, challenges, opportunities and solutions to support the deployment of distributed renewable electricity generation technologies (see Box 1).

Table 3: **Stakeholders and their perspectives/concerns**

Stakeholder	Perspectives / concerns
Electric utility	Technical: - Grid integration and reliability - Power quality - Energy demand peaks Operational/financial: - Potential loss of revenue - Loss of control over generation assets - Perceptions of technology cost and performance
Financial and investment community	- Policy uncertainties and political risks - Expected financial returns - Business risks (e.g. technical performance and regulatory changes) - High initial costs - Competition from subsidized fossil fuel sources - Consumer acceptance
Government	- Grid access rules - Equity and distributional impacts - Allocation of costs and benefits
Consumers	- Price of electricity - Reliability of systems and electric services - Up-front investment requirements - Lack of information/awareness related to technologies - Consumption habits

Box 1. Case study: "Energising Development" in Indonesia

An innovative initiative in Indonesia that supports access to electricity in rural areas, using distributed renewable electricity generation technologies, illustrates the challenges and opportunities of such systems. "Energising Development" (EnDev) Indonesia has supported the installation of over 500 mini-grids, providing electricity to more than 225,000 people. Two technologies are used: micro-hydro systems of 5–200 kW capacity and PV systems of 15–150 kW capacity. Throughout the initiative's implementation, the following key challenges to rural electrification using distributed renewable electricity generation technologies have been identified:

- Institutional aspects, notably a lack of coordination across governmental programmes, and issues on ownership of land and the facility;
- Management aspects, notably ensuring sufficient in-village operational and management skills, and setting tariffs that meet all stakeholder needs;
- Post-installation issues, notably ensuring sufficient technical knowledge and funds for continued operation and maintenance of the facility.

To address these challenges, EnDev Indonesia offers several solutions, such as a 'mini-grid service package', which comprises technical support, village participation schemes and feedback mechanisms. EnDev Indonesia is also monitoring and maintaining site information, including data visualization with the use of a consolidated map. Throughout the years of support activities in Indonesia, it has been observed that the availability of the technology is not the main issue, but rather its applicability to local conditions (Suryani, 2015).

4 Benefits of Distributed Renewable Electricity Generation

In addition to providing electricity, the deployment of distributed renewable electricity generation technologies can bring very important benefits. By replacing electricity generated by fossil fuels, the use of distributed renewable electricity generation can reduce GHG emissions, thus contributing significantly to mitigation action.

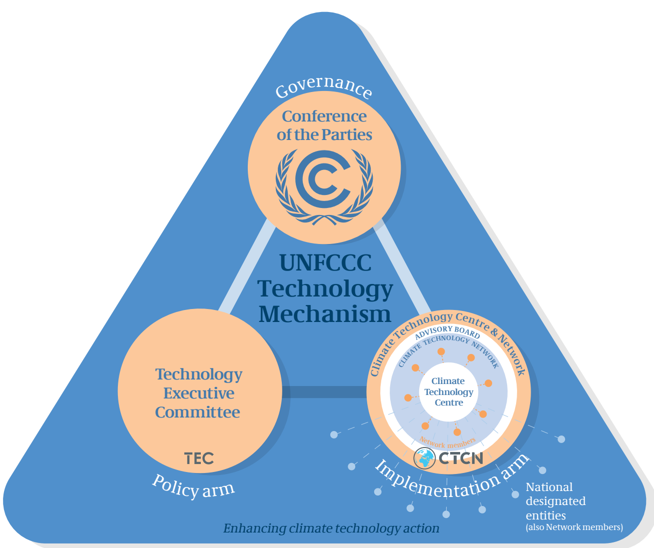
Little data exists on the mitigation potential worldwide from distributed renewable electricity generation. Based on a country-by-country assessment of existing national renewable electricity plans, preliminary estimates by the International Renewable Energy Agency indicate an additional mitigation potential of 0.5–0.6 gigatonnes of carbon dioxide equivalent (Gt CO_2 eq) of avoided GHG emissions per year in 2030 through on-grid distributed renewable, and 0.8–0.9 Gt CO_2 eq of avoided GHG emissions per year in 2030 for off-grid distributed renewable.[2] The distributed renewable electricity generation options that have been assessed are:

- Solar PV systems on rooftops;
- Individual wind turbines connected to low-voltage networks or deployed in off-grid systems;
- Run-of-river hydropower plants (<10 MW);
- Small-scale biogas plants;
- Distributed renewable electricity generation in off-grid systems.

In addition to mitigation benefits, distributed renewable electricity generation can provide very important co-benefits to communities, which are often more relevant to the needs and interests of users and policymakers in developing countries. These include enhanced energy security, reduced local air pollution and reduced dependence on imported fuels.

5 Policy Options

Policymakers have a critical role in facilitating deployment of distributed renewable electricity generation technologies. The UNFCCC Technology Mechanism, with its two components – the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN) – can play an important role in supporting policymakers by providing recommendations and direct technical assistance to develop effective policies.



The growing body of on-the-ground experience in the use of distributed renewable electricity generation technologies, the barriers to their deployment and the diversity of stakeholders with their perspectives and concerns point to a number of policy options that can facilitate greater deployment and absorption of these technologies. Such policy options can be subdivided into three broad categories:

- Build in-country capabilities;
- Develop and implement sound policy and regulatory frameworks for technology deployment;
- Stimulate robust private-sector involvement and investment.

[2] These estimates are based on life-cycle GHG emissions, including avoided black carbon emissions due to the replacement of kerosine lamps.

Build in-country capabilities

CAPACITY-BUILDING NEEDS

Traditionally, knowledge about the production and management of power systems was located in national utilities, while technology development and transfer was supported by large international engineering and specialized consultancy firms. With a wider range of stakeholders involved in distributed renewable electricity generation, it is critical to build both short-term and long-term in-country human and institutional capabilities, for both the public and private sectors, including local communities.

Effective capacity-building should enable countries to fully deploy distributed renewable electricity generation either for technologies imported from other countries, or for technologies adapted to local conditions or developed nationally, for example, PV, wind and mini-hydro technologies. Such action may also help countries to develop and strengthen their national systems of innovation, which is a critical tool to enhance climate action.[3]

For the public sector, key needs include the knowledge and skills to:

- Collect high-quality data and undertake appropriate studies (e.g. economic and resource evaluation) to support policy and regulatory decisions;
- Develop and enforce fair and appropriate policies, regulations and standards (including quality guarantees);
- Facilitate demonstration and pilot projects.

Local and small businesses would benefit from enhanced understanding of technical and economic issues related to distributed renewable electricity generation technologies. A compelling business case for such technologies is needed, which requires business and financial skills, in order to determine if these systems can be achieved at costs similar to those of traditional systems, while providing co-benefits to the community.

Local communities are also critical stakeholders, and need improved energy literacy and awareness, organizational and entrepreneurial skills, and technical skills to operate and maintain distributed renewable electricity generation technologies in a sustainable manner.

BENEFIT FROM INTERNATIONAL COOPERATION

Many agencies and support organizations worldwide have considerable expertise in distributed renewable electricity generation technologies. These organizations, such as the CTCN, can assist in deploying and transferring technologies, particularly for 'soft technologies',[4] for example, through:

- Training programmes and other capacity-building support;
- Enhanced sharing of technology data and analysis tools;
- Programmes to assist in research and development as well as in adapting technologies to local needs;
- Support for local technology certification and testing;
- Methodologies and models of business cases;
- Advice on preparing projects seeking financial support;
- Technical assistance on development of necessary policy frameworks for successful, sustained deployment of distributed renewable electricity generation.

Photo: Nino Brisal – On-site operator training, minigrid facility in Nusa Tenggara Barat, Indonesia

[3] More information may be found in the TEC Brief on strengthening national systems of innovation to enhance action on climate change (November 2015).
[4] Critical to sustainable technology development and transfer, the term 'soft technologies' usually refers to activities in the field of capacity-building, behavioral change, building information networks, training and research.

Develop and implement sound policy and regulatory frameworks for technology deployment

APPROPRIATE POLICIES

The deployment of distributed renewable electricity generation technologies has been driven so far by policies to reduce GHG emissions, improve rural electrification and stimulate economic development. However, the particular modular and production characteristics of these technologies may require new specific policies for the development and management of distributed power systems, as current policies were mainly designed for centralized generation.

For grid-connected systems, policies must be designed in a way that matches the technical reality of the grid to ensure effective integration of distributed renewable electricity, yet promoting technical innovation. Policies also need to include provisions for quality control of power management systems and components, for example of PV systems, and measures to ensure the security of investments.

Policies may not only need careful design and thoughtful implementation, but also ongoing monitoring, evaluation and fine-tuning. As such, policy development should be thought of as an ongoing process rather than a one-off event. As observed in case studies, policy development and implementation require effective coordination across government ministries, institutions and agencies.

VALUE CO-BENEFITS

The deployment of distributed renewable electricity generation technologies can bring very important co-benefits to communities. Policies to further their deployment should recognize these benefits in their analyses of cost-effectiveness, and build coalitions of stakeholders who value such benefits.

RETHINK PUBLIC- AND PRIVATE-SECTOR ROLES IN ELECTRICITY SUPPLY

In many countries, electricity supply is historically a public function. However, the continued development of distributed renewable electricity generation means that opportunities for direct private-sector involvement in electricity supply will expand. Changes may be needed in the energy industry structure because current models were developed for traditional, centralized generation. New institutional mechanisms or frameworks may be needed to allow for both public- and private-sector participation in electricity generation.

WORK WITH ELECTRIC UTILITIES TO FACILITATE DEPLOYMENT

Electric utilities are and will remain key stakeholders, even though the traditional energy structure may have to be adapted for the deployment of distributed renewable electricity generation technologies. Governments should consider how electric utilities could be encouraged to facilitate the deployment of such technologies. Such engagement should address how to deal with integration of variable renewable electricity, including the provision of different services (different from base load and peak load plants as in the traditional model), as well as innovation. Electric utilities will need to tackle the following technical issues:

- Electricity loads, customer and community needs, and the effects of distributed variable electricity generation on the grid;
- Roles for technologies that can support distributed renewable electricity generation, including for smart grids and demand responses;
- Roles for technology standardization and practitioner licensing.

Photo: "Wairakei geothermal power station in New Zealand", Pi-Lens/iStock/Thinkstock

Stimulate robust private-sector involvement and investment

Greater private-sector involvement will be crucial to widespread deployment of distributed renewable electricity generation technologies. This is of great potential benefit, as it will bring new sources of capital for investment. While the policy options outlined above will contribute to stimulating private-sector interest, the specific measures below may help to further attract private-sector investment.

BALANCE FINANCIAL INNOVATION AND REGULATION

Financial innovation from the private sector is needed to support the implementation of distributed renewable electricity generation in some areas. Examples include leases for rooftop PV systems, aggregation and securitization of debt, and community-owned systems.[5] This innovation carries a certain amount of risk and the need for appropriate regulation. Governments may want to address the challenging topic of how to balance their support of innovation with their responsibility to provide appropriate regulation, attempting to strike an equilibrium between risks and rewards for private-sector investors and financiers.[6]

REDUCE FINANCIAL RISKS

Robust private-sector investment and activity are critical to full deployment of distributed renewable electricity generation technologies. There must be some means to minimize financial risks while providing the appropriate rewards to attract the private sector. Experience to date has suggested that the perceived risks may be higher than those that investors consider to be optimal. In addition to sound policy and regulatory frameworks, governments may also take additional steps, notably through providing more certainty around revenues, especially in the first stage of deployment. Examples include feed-in-tariffs,[7] industry-funded insurance pools, and standardized contracts and contractual processes. Measures to facilitate the implementation of effective and proven business models can also stimulate private-sector interest.

RETHINK FOSSIL FUEL SUBSIDIES

Historically, some governments have subsidized diesel for electricity generation in order to provide electricity to those who do not have it or who are unable to pay for it. Governments may now want to re-examine these diesel subsidies, which distort the business case for deployment of distributed renewable electricity generation technologies, and consider other technological routes that can provide electricity at lower economic and environmental costs. Such analyses should also consider the benefits of limiting import dependence and reducing exposure to fuel price variability, while allowing for public funds to be reallocated to other societal needs and services, such as healthcare, education and security.

REASSESS IMPORT DUTIES AND TAXES

Distributed renewable electricity generation has high up-front capital costs, but low operating costs. Consequently, import taxes and duties on distributed renewable electricity generation technologies raise the costs of these technologies and thereby delay their implementation. Governments may want to reconsider these taxes and duties, and determine whether their potential benefits (presumably, support and protection of domestic manufacturing) outweigh the costs of delayed implementation.

[5] For example, in 2014, a large rooftop solar system company based in the United States of America issued USD 70 million in asset-backed securities, and used those funds to support new PV installations.
[6] An example is a requirement for an electric utility (or other energy provider) to procure a minimum amount of distributed generation as part of its overall electricity mix. This sets a guaranteed minimum market size for distributed generation, but still provides for price competition among distributed generation providers.
[7] More information may be found in the TEC Brief on enhancing access to climate technology financing (November 2015).

6 Other Possible Actions by the Technology Executive Committee

In addition to providing policy recommendations, as presented above, the TEC can undertake other actions to facilitate deployment of distributed renewable electricity generation technologies, inter alia:

- Provide advice to and assist the Financial Mechanism, for example, on the technology needs of developing countries related to renewable electricity and on enabling environments to put in place;
- Share best practices and lessons learned and provide recommendations to the technical examination of opportunities with high mitigation potential in the period 2015–2020 (in relation to decision 1/CP.20) to support countries in the identification and implementation of policy options, practices and technologies.

"In addition to providing electricity, the deployment of distributed renewable electricity generation technologies can contribute significantly to mitigation action and provide very important co-benefits to communities."

References

- International Energy Agency (IEA). 2014. Medium-Term Renewable Energy Market Report 2014 – Market Analysis and Forecasts to 2020. Paris: IEA.
- International Renewable Energy Agency (IRENA). 2015a. Renewable Power Generation Costs for 2014. Abu Dhabi: IRENA.
- International Renewable Energy Agency (IRENA). 2015b. IOREC 2014: Accelerating Off-Grid Renewable Energy, Key Findings and Recommendations. Abu Dhabi: IRENA.
- Komor P. and Molnar T. 2015. Background Paper on Distributed Renewable Energy Generation and Integration, prepared for the Technology Executive Committee, United Nations Framework Convention on Climate Change. Available at <http://unfccc.int/ttclear/templates/render_cms_page?s=TEC_TD5>.
- Suryani A. 2015. Case Study: Implementation of the Initiative Energising Development (EnDev) in Indonesia with Micro-Hydro and Solar PV Power, presented at the TEC Thematic Dialogue on Distributed Renewable Energy Generation, Bonn, Germany. Available at <http://unfccc.int/ttclear/templates/render_cms_page?s=TEC_TD5>.
- Technology Executive Committee. 2015. TEC Brief on Strengthening National Systems of Innovation to Enhance Action on Climate Change. Bonn: UNFCCC.
- Technology Executive Committee. 2015. TEC Brief on Enhancing Access to Climate Technology Financing. Bonn: UNFCCC.
- United Nations Framework Convention on Climate Change (UNFCCC). 2013. Third Synthesis Report on Technology Needs Identified by Parties not included in Annex I to the Convention (FCCC/SBSTA/2013/INF.7). Bonn: UNFCCC.

Acknowledgements: The Technology Executive Committee extends its appreciation for the expertise and inputs provided by representatives of observer organizations in the development of this TEC Brief.

Photo: "A photovoltaic system of solar cells", Stocktrek Images/Stocktrek Images/Thinkstock

Contact Details

The Technology Executive Committee may be contacted through the United Nations Climate Change Secretariat (UNFCCC):

Platz der Vereinten Nationen 1, 53113 Bonn, Germany
E-mail: tec@unfccc.int
Website: www.unfccc.int/ttclear/tec

About the Technology Executive Committee

The Technology Executive Committee (TEC) is the policy component of the Technology Mechanism, which was established by the Conference of the Parties in 2010 to facilitate the implementation of enhanced action on climate technology development and transfer. Along with the other component of the Technology Mechanism, the Climate Technology Centre and Network, the TEC is mandated to facilitate the effective implementation of the Technology Mechanism.