

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

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## Renewable Energy: Global Challenges

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LADA V. KOCHTCHEEVA, MAY 27 2016

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Developing renewable energy sources contributes to alleviating poverty, fuelling industrial production and transportation, expanding rural development and protecting health while promoting sustainability and environmental quality (Hostettler, 2015). Renewables account for approximately 20 per cent of global final energy consumption, with the most prominent growth happening in the power sector and with global capacity rising more than 8 per cent in 2013 (IEA, 2014a). Fossil fuels, however, continue to dominate global primary energy consumption, with coal remaining the major contributor to the world's energy pool (REN21, 2014). Almost 1.3 billion people in the world, mainly in rural areas, live without access to electricity and 2.7 billion without modern reliable energy services (UNDP, 2013; Alliance for Rural Electrification, 2014; IEA, 2014a). Global energy consumption is projected to rise by 56 per cent by 2040, with fossil fuels dominating the energy grid (US EIA, 2013). Strong economic and continued population growth in developing countries will be the prevalent force driving world energy markets during that period. Coal use is on the rise, mainly due to China's consumption, and global energy-related carbon dioxide emissions are predicted to have a 46 per cent increase by 2040, a rise from about 31 billion metric tons in 2010 (US EIA, 2013).

These developments have been prompting efforts to deploy renewable energy sources in many countries of the world to make access to energy more sustainable and address the problems of air quality and climate change. The United Nations (UN) has declared the years 2014–2024 the decade of Sustainable Energy for All (United Nations, 2015). Renewable energy technologies, which are a part of the low-carbon facet of global energy supply, are rapidly increasing their presence in many countries of the world. The top five countries for total installed renewable power capacity by the beginning of 2014 were China, the United States (US), Brazil, Canada and Germany. In the European Union (EU), renewables have represented the majority (72 per cent) of new electric generating capacity for the last several years (REN21, 2014). Renewables, however, are no longer dependent on a small number of countries. Major renewable energy companies became very interested in Africa, Asia and Latin America; where new markets are emerging on and off-grid. Investment patterns are also shifting away from traditional governmental and foreign donor sources to greater reliance on private and often local firms and banks (Martinot et al., 2002; REN21, 2014). Support for the adoption of renewable energy has been growing among the governmental agencies, industry, non-governmental organisations and the public at large. These actors pursue energy, environment and development agendas at local, regional and global levels (Bayer et al., 2013; REN21, 2014).

The policy, manufacturing and financing for renewables continue to expand across the developing world and emerging economies. By 2018, according to the International Energy Agency (IEA), non-OECD countries are predicted to account for 58 per cent of total renewable generation, up from 54 per cent in 2012. Renewable energy generation in most developing countries still mostly depends on inexpensive and abundant hydropower, but other technologies are on the rise in countries with good resources and emerging support measures (IEA, 2013).

Helped by global subsidies, renewables may account for almost half of the increase in total electricity generation to 2040, with the use of biofuels more than tripling (IEA, 2014b). Generation of renewables is also predicted to rise more than twice as much in many developing countries and emerging economies. The number of developing countries with policies in place to support renewable energy has increased sixfold since 2006, resulting in one-fifth of

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

the world's power production presently coming from renewable energy sources (United Nations, 2014). Continuing advances in technology, innovations in policy and financing, decreasing prices, and educational efforts make renewables more attractive and affordable for a larger number range of consumers around the world (REN21, 2014).

However, as renewable energy policies, markets and industries develop, they increasingly face new challenges, which are multifaceted and highly complex. The fact that significant reserves of fossil fuels are still available impedes the willingness to give sufficient importance to the renewables. Fossil fuels receive six times more in subsidies than renewable energy sources (Hostettler, 2015). In their competition with mature fossil fuel and nuclear technologies, renewables encounter major challenges to commercialisation, including underdeveloped infrastructure and lack of economies of scale. Additionally, the integration and combination of different energy sources from a market, policy and technical perspectives are becoming more challenging and requiring capacity building. The success of deploying new technologies depends on the ability to build, monitor and maintain energy infrastructure, as well train scientists, decision-makers and manufacturers at domestic and global levels (MacLeod and Rosei, 2015).

For developing countries, especially, costs and the lack of sound policies are some of the main barriers. Start-up expenditures, the lack of approaches to balance price disparities between renewables and fossil fuels, and overarching structural obstacles, such as the centralised nature of the energy industry, impede support and implementation of new initiatives, deter investment in renewables and frustrate more localised approaches to energy access. Notably, the introduction of renewables presents an issue of inequality. The problem is that the rate of technology diffusion, the availability of financing and policy implementation are uneven within and across countries' national boundaries. And while renewable energy is one of the world's fastest-growing energy sources now, increasing by 2.5 per cent per year (REN21, 2014), it has not been sufficient to keep pace with the consequences of rapid growth in demand for energy.

Employing renewable energy faces a range of economic, policy, structural and social challenges, requiring not only further technological development and investment but also a deeper understanding of both the success factors and the obstacles to accomplish widespread adoption. This chapter will proceed by presenting the discourse on the deployment of renewable energy with an emphasis on policy, technology and investment for renewables in the developing countries. It will continue with the discussion of some of the major international challenges that may explain the difficulties in the adoption and implementation of renewable energy, including the effects of global learning on the introduction of renewables, the barriers to technology and policy diffusion. The chapter ends with concluding remarks.

## Policy, Technology and Investment Considerations for Renewable Energy

Countries around the world increasingly take measures to research and deploy renewable energy sources to improve energy security, encourage economic growth and respond to environmental challenges particularly associated with climate change. The research by the International Energy Agency demonstrates that renewable energy technologies have been mainly adopted by countries with relatively high gross domestic product (GDP) per capita and also high energy security concern (Müller et al., 2011). Such front-runner countries have both the capacity and the impetus to engage with renewables especially during the initial development stages, when costs are high. The wealth of these countries also influences the choice of the technology for generating renewables, where countries with lower economic capacity focus on lower-cost, well understood and established renewable sources, such as hydro and biomass. With the increasing maturity of renewables, falling prices, enhanced education and improving competitiveness, the likelihood of technology diffusion across national boundaries increases. For many developing countries, the opportunities to deploy renewable energy sources exist particularly in cases where the resource conditions are good and the need for expansion in energy access is high (Müller et al., 2011).

The majority of developing countries are blessed with substantial renewable energy resources, such as solar and wind, covering large geographical areas and not requiring a centralised approach for dissemination. The deployment of renewable energy can make effective use of available human capital in countries with underemployment without compromising the desirable features of energy supply. The rationale for the adoption of renewables is strengthened both by the improvement in the quality of life of rural, distant, under-served populations and by the devastating

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

environmental effects of fossil fuel use. Additionally, for developing countries the stakes of dealing with environmental consequences are much higher than for developed nations. Yet, the capacity of developing countries to manage severe environmental degradation and its health consequences is often inadequate and undermined by their vulnerability to external shocks either financial or environmental.

Developing countries also have a number of common characteristics that influence the acceptance, spread and sustainability of renewable energy approaches (Kandpal et al., 2003). The most important feature is the desire for economic development and a constant trade-off between growth and environmental protection (Mohiuddin, 2006; Hostettler, 2015). The majority of the population has low, or relatively – compared to the developed countries – lower energy consumption per capita, which reflects poorer quality of life and low purchasing power of potential end-users of renewable energy. Many of the developing countries import fossil fuels, which creates risks for energy security and foreign exchange. And while developing countries have experience with renewable energy technologies, projects, especially in the past, were characterised by fragmented efforts and were implemented in isolation from other development challenges such as health, education and local development. Additionally, up until the 1990s, renewables were introduced without the guidance of integrated policies (GNESD, 2007). So, the priority for many developing countries became the creation of supporting policies for the adoption of renewables.

## *Policy*

The introduction and implementation of support policies to a large degree determine the extent to which renewables are developed in a country (Berg, 2013). The renewable energy market is also a policy-driven market. The adoption of support policies, however, does not follow the one-size-fit-all approach. The choices of policy instruments and sectors need to reflect the objectives of each country according to its priorities regarding environmental protection, economic development and socio-economic structure (Djiby, 2011). Also, while a particular policy approach may be considered as effective, public expenditures required to achieve this might be disproportionate and therefore politically unbearable. Determining the costs and risks of various policy tool kits involves multiple, complex assumptions and considerations of country market structure, resource endowments and national goals (UNDP, 2013).

Developed countries usually serve as front runners in establishing new policies. For example, in Europe, new policies are emerging to accelerate or manage the integration of renewables into existing power systems, including the development of energy storage and smart grid technologies. Developing countries are adopting support policies and experimenting with various policy tools. By the end of 2013, developing and emerging economies became the leaders in the increase of renewable energy support policies and accounted for 95 of the 138 countries with such policies (REN21, 2014). Renewable energy support policies usually include the use of regulatory and economic instruments such as standards, planning and codes; building institutional structures and capacity; as well as voluntary approaches, including information provision, advertisement, and education. The latter policy tools are only in their nascent stages in developing countries, with most emphasis on economic tools such as direct investments in infrastructure, fiscal and financial incentives and market-based initiatives, including allowances for greenhouse gas (GHG) emissions or green certificates. Specifically, feed-in tariff policies (policies based on prices) and renewable portfolio standards (RPS) (policies based on quantities) are the most commonly used policy support mechanisms. Regulatory policies, as well as economic instruments, have been found to have a strong effect on the production of renewable energy in the developing world. (Pfeiffer and Mulder, 2013)

Most renewable energy policies enacted or revised focus on the power sector, yet a big challenge for the renewable energy industry, in general, has been competition from heavily subsidised conventional energy. Other significant policy challenges for the developing countries and emerging economies include the problems of policy formation in the context of economic development, where growth is a priority and where old and entrenched mechanisms are difficult to part with. Households or energy companies which want to install wind turbines or solar panels have been discouraged by lengthy pay-back times. Without political measures to facilitate access to the market and increased consumer demand, manufacturers of wind turbines or solar photovoltaic (PV) panels cannot produce the unit volumes needed to bring prices down and drive technological innovation.

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

Another challenge is the creation of an enabling policy environment and targets that can encourage the private sector to participate in financing the development of renewable energy projects (UNDP, 2013). Supporting renewable energy demonstration projects to spread information in remote areas, training microfinance leaders and decentralising the implementation of renewable energy projects may foster the spread of renewable energy projects. Such actions would also help build a better equipped sustainable renewable power industry, generate profits and create jobs, as well as increase efficiency in financing (Mohiuddin, 2006; MacLeod and Rosei, 2015). Most support for renewable energy policies and technologies in developing countries comes from local governments or from international donors, which undermines their sustainability, as the funds fluctuate with changing priorities and crises.

Finally, the establishment of innovative policies and sustainability of renewable energy markets and technology may benefit from the adoption of an overall energy governance framework. The introduction of energy governance enables more efficient involvement of various stakeholders, increasing the decision-making authority of local governments, creating diversified institutional arrangements and public involvement (Djiby, 2011), as well as increasing capacity to tailor policy to local conditions, especially in countries with wealth disparities and varied commitments to environmental improvement.

## *Technology*

The choice and deployment of renewable energy technologies may significantly contribute to building a comprehensive strategy towards more sustainable economic growth. Technological innovation and capacity in renewables result from a broad range of factors and not merely from effective research and development efforts (Müller et al., 2011). These include technological capability of a country, innovation-friendly regulation, market conditions that favour adaptive learning, and others. Specifically, a study of patent activity demonstrates the relative strength of different developed countries in generating technology innovation and using their pioneering country advantage in renewables. For instance, Germany and Denmark exhibit strength in wind energy technologies, the United States, Germany and Japan show the highest shares of patents for solar PV technology, and the EU as a whole presents the largest patent shares for biomass and biogas, wind and solar thermal technologies (Müller et al., 2011). The emerging challenge with the adoption and spread of renewable energy technologies is twofold. The first is whether these pioneer countries can sustain their first-mover advantage in the face of growing competition from emerging economies with lower production costs. While renewable energy innovation has traditionally been the prerogative of the developed world, it is now on the rise in the emerging economies. BRICS countries rank among the top global inventors (Bayer et al., 2013). The biggest limitation, however, is that these countries do not yet export their technologies to either developed or other developing countries on any substantial scale.

The second concern is whether many low-income developing countries are able to secure the diffusion of these technologies, as well as create conditions for the development of domestic renewable energy technologies (Ockwell and Mallett, 2012). Due to the relatively high upfront costs of most technologies, having access to finance is considered to be an important prerequisite for their adoption (Kandpal et al., 2003; Brunnschweiler, 2010; Huenteler et al., 2014). As such, higher level of economic development tends to influence the level of renewable energy development, because the former usually suggests more public and private financial resources, increasing environmental awareness and growing electricity demand (Pfeiffer and Mulder, 2013). Globally, there has been a discernible trend in lowering costs and improving efficiency of renewable technology installations, making it possible to build onshore wind and solar PV installations in certain areas around the world without subsidy support, particularly in Latin America. There has also been an increased use of mini-grids, which supported the dissemination of renewable energy-powered electrification in rural and suburban areas with poor electrification (Müller et al., 2011). With the help of information and communication technology for power management and end-user services, technical advances that allow the integration of renewable sources in mini-grid systems, stimulated a rapid expansion of the use of renewables-powered mini-grids in developing countries (REN21, 2014).

## *Investment*

Renewable energy sources are progressively being viewed as investments that can generate economic advantages by reducing dependence on foreign fossil fuels, improving air quality and health safety, increasing energy access and

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

security, building opportunities for economic development and reducing unemployment. Global investment in renewable power capacity and fuels increased more than fivefold over the period 2004–2013. Total global investment (both public and private) in research and development for renewable energy technologies has almost doubled over the past decade (REN21, 2014).

The portrait of renewable energy development is, however, becoming more multifaceted, with more challenges seen in some regions of the globe. While new global investment in renewable energy remains relatively high, there is observable decrease in the last several years. Global new investment in renewable power, without hydropower projects, was US\$214.4 billion in 2013 (REN21, 2014), which was down 14 per cent relative to 2012, and 23 per cent lower than the record level in 2011 (Frankfurt School-UNEP, 2014). The reduction in investments for two consecutive years was mostly due to uncertainty over support policies in Europe and the United States and retroactive reductions in support in some other countries. While Europe's investment was down by more than 40 per cent, the emerging economies are coming to the forefront for the first time, with China alone having invested more in renewable energy than all the European countries (REN21, 2014). Economic difficulties, policy uncertainties, reductions in incentives and strong and persistent competition from traditional energy sources played the role in the investment volume. Different countries in the world specifically experienced challenges in integrating renewables in their power grids, while the manufacturing sector, especially wind and solar, moved into a complex phase of restructuring and consolidation (IEA, 2013).

Additionally, renewable energy sources are being introduced into an uneven playing field, where their energy prices do not fully reflect externalities. Global subsidies for traditional fuels and nuclear energy remain high despite the benefits of renewables and environmental quality concerns. Estimates for the global cost of fossil fuel subsidies range from \$544 billion to \$1.9 trillion – several times higher than those for renewable energy (REN21 2014). A large part of renewable capacity additions is found in countries with extensive subsidy systems, which can compensate investors for the comparatively high costs of the renewable energy technologies (Wagner, 2014). Although renewable energy technologies have undergone significant cost reductions in the last several years, they are still comparatively immature and much less able than traditional sources of energy to provide cost-competitive power generation on a large scale. Especially in developing countries, the barriers towards a larger transition to renewable energy are not just the disproportionate subsidies and technology costs but also the challenges of securing long-term commitment and affordable finance (UNDP, 2013).

## Global Learning and Diffusion of Policy and Technology

Because high upfront costs and disproportionate financing remain some of the major challenges for large-scale commercialisation and adoption of renewables, especially in developing countries, the question becomes how to facilitate the development and diffusion of renewable energy technologies and policy approaches (Schmidt, 2014). As the industries producing renewable energy technologies are becoming increasingly globalised (Huenteler et al., 2014), the conditions of global learning, the paths of technology diffusion and the characteristics of the front-runner and borrower countries influence adoption and transfer of renewable energy technologies.

### *Global Learning*

The spread of renewable energy technologies, especially in developing countries and emerging economies, depends on the combination of global and local learning processes, which, in turn, depend on domestic and international policy provisions and local institutional and industrial contexts (Huenteler et al., 2014). Building technological capabilities through learning is viewed as an important contributing factor in the deployment of renewable energy sources that can result in cost reductions, performance improvement and climate change mitigation efforts (Ockwell and Mallett, 2012; Lema and Lema, 2013). Increased technological capacity — the accumulation of technological knowledge and experience — is essential for building local capacity for production, poverty reduction and socio-economic development. However, technological capabilities comprise not only the information, materials and components but also the skills and well developed routines. This means that technological learning demands the development of local capacities in addition to the removal of trade barriers, provision of intellectual rights and other forms of technical assistance (Huenteler et al., 2014).

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

Individuals and firms learn and innovate via their collaboration with research institutes, consumers, suppliers, competitors, etc. The formation of formal and informal networks, as well as a system of financing for research and development, is an important requisite for technological learning. Domestic positive policy and investment climate may influence and increase technological capacity through learning, yet it is not the single function for technology advancement. Acquired technological capacities can risk decline in the absence of a domestic support policy framework, stable financing and an accepting culture. The significant task is to create domestic opportunities and an atmosphere for continuous learning for governments, firms and communities through the build-up of organisational processes and culture, support of science and education, as well as various systems for innovation.

Technological learning has an ever-evolving global component composed of the movement of goods, services, materials, documents and information where many parts of supply chains are geographically dispersed and disintegrated. The markets for renewable energy technologies have also become globalised. The aggregate global market knowledge and trends to a large degree stipulate the development of technological capacities in firms and industries beyond domestic and local circumstances (Huenteler et al., 2014). Timely and reliable data on renewable energy are also crucial for creating energy plans, outlining criteria for targets, examining progress and effectiveness of policy actions and generating investment. Global data collection on renewables demonstrates an improvement with more broad and sensible record keeping, increased openness and better communication among stakeholders. However, there are many challenges remaining. In many countries, data on renewable energy are incomplete, not collected systematically, and with a time lag between developments and availability, which can be a significant impediment to relevant and timely decision-making process. Additionally, the large number and diversity of technologies in certain sectors, such as heating and cooking, may also lead to the dispersed and inconsistent data collection (REN21, 2014). This, in turn, can cripple the capacity to make informed decisions and affect financing opportunities, policy outcomes and planning for the future.

## *Diffusion of Policy and Technology*

The dynamics of the global system and information flows also stand out as an important set of requisites influencing diffusion of renewable energy policy and technology. Diffusion is a process by which policy, technology and innovations are communicated throughout the international system over time (Jørgens, 2005). The role of international organisations, transnational networks and political linkages between states, the influential role of frontrunner countries and the institutionalisation of policy transfer shape the mechanisms of diffusion (Kern et al., 2001; Tews, 2005). Among many international factors, the role of front-runner states is critical for diffusion, as their expertise, economic strength, demand for environmental solutions and desire to influence others all impact on whether a policy diffuses effectively (Graham et al., 2013). Acting first in the adoption of renewable technology may give a country the ability to 'defend their own interests by assuming an active, pioneering role' (Kern et al., 2001: 5). In addition to regulatory advantages, leader nations may have a market advantage in renewable technology. Policy innovations in leader countries can set international standards, which put pressure on other countries to adopt similar policy (Kern et al., 2001). This regulatory conformism can lead to group behaviour in policy making and contribute to diffusion.

Diffusion of renewable energy policy and technology embodies the flows of information, experience and equipment for the adoption of renewable energy sources among various stakeholders, such as governments, firms, financial institutions and other entities. The diffusion may provide an adopting country the capacity to implement, operate and maintain borrowed technologies and policy measures to local conditions. The spread of renewable technology and policy may not be easy and straightforward for developing countries where immediate financial and institutional constraints are likely to be more acute than in most developed countries. Diffusion mechanisms must be responsive to the particular needs and challenges of developing countries and must advance, to the greatest extent feasible, multiple societal objectives. In countries where a significant portion of the population still lacks access to basic stable energy services, concerns about long-term environmental sustainability often are surpassed by more pressing problems of energy access and affordability.

In general, it has been demonstrated that the diffusion of renewable energy technologies depends on the implementation of economic and regulatory instruments, per capita income and schooling levels and stability of the

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

regime (Pohl and Mulder, 2013). A thorough understanding of domestic resources and knowledge of policy measures that have been successfully applied in other countries also influences the prospects of adoption of efficient and context-specific measures for the renewable sources. A combination of measures to build a coherent enabling framework is important to ensure cost-efficient transfer and diffusion of a specific technology. Especially in developing countries, there is a need for targeted technical assistance that incorporates social equity components, not jeopardising low-income consumers but still attractive to both private and international aid organisations (UNEP, 2011).

## Conclusions

Although the adoption of renewable energy sources is increasing in many parts of the world, widespread adoption is constrained by a multitude of policy, regulatory, technological, social and financial barriers. Enormous subsidies for fossil fuels and nuclear power persist, and they continue to vastly outweigh financial incentives for renewables. Market failures coupled with unfavourable financial, institutional and regulatory environments demand governmental intervention to establish renewable energy sources. Building human and institutional capacity, setting up research and development infrastructure, creating an enabling environment for investment and providing information present a challenge for many countries. A lack of supporting policy framework also stands as a large barrier among the risks that can undermine renewable project feasibility, even in the conditions of plentiful resources and favourable technology development. This array of challenges to the adoption of renewables requires a systematic approach in research to deepen the understanding of the challenges that exist for the deployment and diffusion of renewables in different countries. The exact difficulties that countries face depend upon national circumstances, the dynamics of the global system and the flows of information and resources. Devising effective responses to a problem that is global and multi-generational in scale presents a challenge that is, especially for developing countries, greatly complicated by the simultaneous need to expand access to essential energy services and to advance multiple objectives, including economic and social development goal as well as environmental ones.

## References

- Alliance for Rural Electrification (2014). *Energy Access in the World*.
- Bayer, P., Dolan, L. and Urpelainen, J. (2013). Global Patterns of Renewable Energy Innovation. *Energy for Sustainable Development*, 17(3), 288-295.
- Berg, S. (2013). Regulatory Functions Affecting Renewable Energy in Developing Countries. *The Electricity Journal*, 26(6), 28-38.
- Brunnschweiler, C. N. (2010). Finance for Renewable Energy: An Empirical Analysis for Developing and Transition Economies. *Environmental Development Economics*, 15(3), 241-274.
- Djiby, R. T. (2011). An Energy Pricing Scheme for the Diffusion of Decentralized Renewable Technology Investment in Developing Countries. *Energy Policy*, 39(7), 4284-4297.
- Frankfurt School-UNEP (2014). FS-UNEP *Collaborating Center*. *Global Trends in Renewable Energy Investment 2014*. Key Findings. Frankfurt School of Finance and Management.
- GNESD (2007). *Renewable Energy Technologies and Poverty Alleviation: Overcoming Barriers and Unlocking Potentials*. Global Network on Energy and Sustainable Development.
- Graham, E., Shipan, R. and Volden, C. (2013). The Diffusion of Policy Diffusion Research in Political Science *British Journal of Political Science*, 43, 673-701.
- Hostettler, S. (2015). Energy Challenges in the Global South. In: S. Hostettler, A. Gadgil, and E. Hazboun (eds). *Sustainable Access to Energy in the Global South: Essential Technologies and Implementation Approaches* (pp.

# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

3-9). London: Springer International Publishing.

Huenteler, J., Niebuhr, C. and Schmidt, T. S. (2014). The Effect of Local and Global Learning on the Cost of Renewable Energy in Developing Countries. *Journal of Cleaner Production*.

IEA (2013). *Renewable Energy. Medium Term Market Report 2013. Market Trends and Projections to 2018*. OECD/IEA.

IEA (2014a). *World Energy Outlook 2014*. OECD/IEA.

IEA (2014b). *Renewable Energy. Medium Term Market Report 2014. Executive Summary*. OECD/IEA.

Jörgens, H. (2005). Diffusion and Convergence of Environmental Policies in Europe. *Environmental Policy and Governance*, 15(2), 61-62.

Kandpal, T. C., Purohit, P., Kumar, A. and Chandrasekar, B. (2003). Study of Selected Issues Pertaining to the Economics of Renewable Energy Utilization in Developing Countries. *Journal of the Solar Energy Society of India*, 13(1-2), 57-82.

Kern, K., Jorgens, H. and Janicke, M. (2001). *The Diffusion of Environmental Policy Innovations: A Contribution to the Globalisation of Environmental Policy*. WZB Working Paper No. FS II 01 – 302. Berlin: WZB.

Lema, A and Lema, R. (2013). Technology Transfer in the Clean Development Mechanism. *Global Environmental Change*, 1, 301-313.

MacLeod, J. M. and Rosei, F. (2015). Supporting the Development and Deployment of Sustainable Energy Technologies Through Targeted Scientific Training. In: S. Hostettler, A. Gadgil, and E. Hazboun (eds). *Sustainable Access to Energy in the Global South: Essential Technologies and Implementation Approaches* (pp. 231-233). London: Springer International Publishing.

Martinot, E. Chaurey, A., Lew, D., Moriero, J. R. and Wamukonya, N. (2002). Renewable Energy Markets in Developing Countries. *Annual Review of Energy and Environment*, 27, 309-348.

Mohiuddin, S. (2006). Microfinance: Expanding the Role of Microfinance in Promoting Renewable Energy Access in Developing Countries. *The Georgetown Public Policy Review*, 11, 119.

Müller, S., Brown, A. and Ölz, S. (2011). *Renewable Energy. Policy Considerations for Deploying Renewables*. Information Paper. OECD/IEA.

Ockwell, D. and Mallet, A. (2012). *Low-Carbon Technology Transfer: From Rhetoric to Reality*. New York: Routledge.

Pfeiffer, B. and Mulder, P. (2013). Explaining the Diffusion of Renewable Energy Technology in Developing Countries. *Energy Economics*, 40, 285-296.

Pohl, B. and Mulder, P. (2013). *Explaining the Diffusion of Renewable Energy Technology in Developing Countries*. German Institute of Global and Area Studies. Paper No. 207. Hamburg: GIGAS.

REN21 (2014). *Renewables 2014. Global Status Report*.

Schmidt, T. S. (2014). Low-carbon Investment Risks and De-risking. *Nature Climate Change*, 4, 237-39.

Tews, K. (2005). The diffusion of environmental policy innovations: Cornerstones of an analytical



# Renewable Energy: Global Challenges

Written by Lada V. Kochtcheeva

framework. *European Environment: The Journal of European Environmental Policy*, 15(2), 63-79.

UNDP (2013). *Derisking Renewable Energy Investment*. New York: UNDP.

UNEP (2011). *Diffusion of Renewable Energy Technologies: Case Studies of Enabling Frameworks in Developing Countries*. Technology transfer Perspective series.

United Nations (2014). *Developing Nations' Policies Push Renewable Energy Capacity to Record High, Says UN-backed Report*.

United Nations (2015). *United Nations Decade of Sustainable Energy for All*.

US EIA (2013). *International Energy Outlook 2013*. DOE/EIA-0484.

Wagner, F. (2014). *Renewables in the Future Power Systems: Implications of Technological Learning and Uncertainty*. New York, Dordrecht, London: Springer.

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## About the author:

**Lada V. Kochtcheeva** received her MS and PhD in Political Science from the University of Oregon. She is currently an Assistant Professor of Political Science in the School of Public and International Affairs at North Carolina State University. Her current research is inspired by contemporary problems of environmental governance, institutional development, government-society relations and comparative public policy. She has published *Comparative Environmental Regulation in the United States and Russia: Institutions, Flexible Instruments, and Governance* (New York: SUNY Press, 2008) – which examines political and policy pre-conditions for the replacement of command and control systems with flexible instruments such as incentive programmes, tradeable permits and pollution charges.