UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

World Small Hydropower Development Report 2019

Executive Summary

Disclaimer

The *World Small Hydropower Development Report 2019* is jointly produced by the United Nations Industrial Development Organization (UNIDO) and the International Center on Small Hydro Power (ICSHP) to provide development information about small hydropower.

The opinions, statistical data and estimates contained in signed articles are the responsibility of the authors and should not necessarily be considered as reflecting the views or bearing the endorsement of UNIDO or ICSHP. Although great care has been taken to maintain the accuracy of information herein, neither UNIDO, its Member States nor ICSHP assume any responsibility for consequences that may arise from the use of the material.

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as 'developed', 'industrialized' and 'developing' are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

Suggested citation:

LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www. smallhydroworld.org.

ISSN: 2406-4580 (print)
ISSN: 2706-7599 (online)

The digital copy is available on www.smallhydroworld.org.

Design: red not 'n' cool
Cover Picture: gregbrave / 123rf.com

Foreword

LI Yong, Director General, UNIDO

On 24 and 25 September 2019 the world leaders, policy-makers, civil society and the private sector gathered in New York to comprehensively review the progress in implementing the 2030 Agenda, a blueprint for shared prosperity in a sustainable world, adopted five years ago. The review highlighted encouraging advancements on many fronts, with concerted action being taken to alleviate poverty and hunger, protect our seas and forests, and make our cities greener and healthier. It also showed that the progress on many crucial goals is too slow: millions of people world-wide still live without reliable access to sustainable energy and clean water, the industrialization rate in sub-Saharan Africa remains below the target and global climate action lacks required ambition. To accelerate the implementation of Sustainable Development Goals and create the future we want by the year 2030, the global community must delineate the best strategies for affordable and concrete solutions.

Small hydropower presents one of such simple, affordable, practical and low-cost solutions. When implemented with environmental and socio-economic aspects in mind, it can simultaneously improve access to energy from renewable sources for remote and vulnerable rural communities, offer employment opportunities for youth, expand possibilities for growth for small-scale businesses, and contribute to combatting of climate change. Small hydropower technologies are easily adaptable for local conditions as well as various geographical and infrastructural circumstances. Moreover, small hydropower installations come with the lowest electricity generation prices in comparison to other off-grid technologies.

However, the potential of small hydropower in developing countries remains largely untapped with only 34 per cent of global potential being utilized. To provide policy-makers with a solid basis for informed decisions and attract prospective financiers to invest in sustainable energy solutions, the United Nations Industrial Development Organization partnered with the International Center on Small Hydro Power to launch this third edition of the *World Small Hydropower Development Report* and the accompanying knowledge platform (www.smallhydroworld.org). The rich content of the report is an outcome of a collective effort of more than 200 authors and contributing organizations from all over the world. The production of this comprehensive report would not be possible without generous support and intellectual leadership from the Ministry of Water Resources of the People's Republic of China.

I am confident that this report will be beneficial not only for sustainable energy stakeholders, but also for the global development community while we are embarking on our ambitious journey to 2030, leaving no one behind.

Acknowledgements

The World Small Hydropower Development Report 2019 was prepared under the overall guidance of Tareq Emtairah, Director of the Department of Energy at the United Nations Industrial Development Organization (UNIDO) and LIU Deyou, Director General of the International Center on Small Hydro Power (ICSHP).

The Report was headed by LIU Heng, Senior Technical Expert at UNIDO and consulted by HU Xiaobo, Chief of the Division of Multilateral Development at ICSHP. This lengthy, and at times, arduous endeavour was coordinated by Eva Krēmere at UNIDO and WANG Xianlai at ICSHP. The Report is the result of three years of intense research efforts and was backed by a talented and indispensable team of researchers at ICSHP and a vast number of experts in the field of small hydropower.

***WSHPDR 2019* team:**

Head	LIU Heng - Senior Technical Advisor, United Nations Industrial Development Organization (UNIDO)
Coordinators	Eva Krēmere - United Nations Industrial Development Organization (UNIDO) WANG Xianlai - International Center on Small Hydro Power (ICSHP)
Communications	Eva Krēmere - United Nations Industrial Development Organization (UNIDO) Oxana Lopatina - International Center on Small Hydro Power (ICSHP)
Team	UNIDO: Eva Krēmere, Sanja Komadina. Interns: Eleanor Vickery, Steven Moser ICSHP: HU Xiaobo, WANG Xianlai, Oxana Lopatina, Ofelia Raluca Stroe, Alicia Chen Luo, Clara Longhi, Georgii Nikolaenko, Riona Lesslar

The invaluable contributions and insightful comments received greatly enhanced the overall quality of the Report:

Advisory Board	Alfonso Blanco Bonilla, Latin American Energy Organization (OLADE); Linda Church-Ciocci, National Hydropower Association (NHA); Dirk Hendricks; European Renewable Energies Federation (EREF); Eddy Moors, IHE Delft Institute for Water Education; Richard Taylor, International Hydropower Association (IHA); Adrian Whiteman, International Renewable Energy Agency (IRENA).
Peer Reviewers	Andrew Blakers, Johannes Geert Grijsen, Sergio Armando Trelles Jasso, Furkat Kadyrov, Wim Jonker Klunne, Galina Livingstone, Miroslav Marence, Niels Nielsen, Michael Panagiotopoulos, Mathis Rogner, Wilson Sierra.
Regional Authors	Engku Ahmad Azrulhisham, Guillaume Binet, Edilbek Bogombaev, Paulo Alexandre Diogo, Pirran Driver, José Fábrega, Cleber Romao Grisi, Richard Hendriks, Michela Izzo, Bryan Karney, Egidijus Kasiulis, Wim Jonker Klunne, Arun Kumar, Miroslav Marence, Niels Nielsen, Daniel Paco, Alberto Sánchez, Mohamedain E. Seif Elnasr, Stafford W. Sheehan, Janusz Steller, Phillip Stovold.

Authors and Contributors

Fagan Abdurahmanov, Donald Adgidzi, Leonardo Aburto, Clément Bill Akouèdénoudjè, Loboso Cosmas Manase Akwenya, Sameer Sadoon Algburi, Mohammad Hassan AlZoubi, Gabrial Anandarajah, Viktor Andonov, Darlene Arguelles, Vicky Ariyanti, Fredrik Arnesen, John Kobbina Arthur, Aleksandra Aubreht, Engku Ahmad Azrulhisham, Betsy Bandy, Bohuslav Barta, Batdelger Batsuuri, Alexis Baúles, Madhu Prasad Bhetuwal, Sow Aissatou Billy, Andrew Blakers, Alaeddin Bobat, Thomas Buchsbaum-Regner, Nebiyu Bogale, Alfredo Samaniego Burneo, Ejaz Hussain Butt, Abou Kawass Camara, Sonya Chaoui, Marco Antonio Jimenez Chavez, Piseth Chea, Chi Chen, Gift Chiwayula, Brenda Chizinga, Nouri Chtourou, Edchilson Cravid, Manana Dadiani, Denise Delvalle, Jovan Despotović, Johanna D'Hernoncourt, Sinalou Diawiara, Camille Augustin Kabasele Dikangala, Fikru Gebre Dikumbab, Paulo Alexandre Diogo, Jonas Dobias, Aurélie Dousset, Choten Duba, Khalil Elahee, Azubike Emechebe, Lambert Engwanda, Haider Khalil Essa, José Fábrega, Giovanna Fantin, Nimashi Fernando, Soukaina Fersi, Geraldo Lúcio Tiago Filho, Sione Foliaki, Danilo Fras, Fombong Matty Fru, Tokihiko Fujimoto, Patrick Furrer, Garaio Gafiye, Camila Galhardo, Morella Carolina Gilarias, Gaelle Gilboire, Florence Gimbo, Carlos González, Cleber Romao Grisi, Leo Guerrero, Mathias Gustavsson, Mohammad Hajilari, Nihad Harbas, Eoin Heaney, Samira Heidari, Richard Hendriks,

Sven Homscheid-Carstens, Arian Hoxha, Maria Ibragimova, Helvi Ileka, Michela Izzo, Frantisek Janicek, Sergio Armando Trelles Jasso, Rim Jemli, Kurt Johnson, Morsha Johnson-Francis, Furkat Kadyrov, J.K. Kaldellis, Rachel Kalebbo, Papias Karanganwa, Bryan Karney, Raúl Pablo Karpowicz, Egidijus Kasiulis, Shorai Kavu, Fredrick Kazungu, Sahib Khalilov, Eva, Kremere, Maris Klavins, Daniel Klinck, Juliet F. Khosrowabadi Kotyk, Dong Hyun Kim, Wim Jonker Klunne, John Korinihona, Arun Kumar, Sarah Acholla Kwach, Mohamed-Yahya Ould Lafdal, Gianluca Lazzaro, Seung Oh Lee, Disashi Nyama Lemba, Jean-Marc Levy, Patricia Lewin, Robert Limoko, Galina Livingstone, Frank Lucas, Esménio Isabel João Macassa, Manuel Mahler-Hutter, Sarmad Nozad Mahmood, Ewa Malicka, Igor Malidzan, Pedro Manso, Ghulam Mohd Malikyar, Sharon Mandair, Luis Manzano, Miroslav Marence, Cayetano Espejo Marín, Ramón Garcia Marín, Rupeni Mario, Anare Matakiviti, Juan José García Méndez, Sierra Method, Luiza Fortes Miranda, Ditiro Benson Moalafhi, Conrado Moreno, Bastian Morvan, Carine Mukashyaka, Reynolds Mukuka, Jaime Muñoz, Wakati Ramadhani Mwaruka, Sandar Myo, Thet Myo, Anna Nadolny, Bilal Abdullah Nasir, N'guessan Pacôme N'Cho, Jami Nelson-Nuñez, Leonel Wagner Neto, Desire Florentin Ngaibona, Peter Norville, Robert Nyamvumba, Abdeen Mustafa Omer, Emna Omri, Karim Osseiran, Sok Oudam, Victor Owuor, Daniel Paco, Domingos Mosquito Patrício, Cláudio Moisés Paulo, Elsia Paz, Henrik Personn, Pihla Pietilainen, Vlad Florin Pîrăianu, Adelino Sousa Pontes, Nuwan Premadasa, Thoeung Puthearum, Peeter Raesaar, Carlos Fernando Moros Ramirez, Laura Lizano Ramon, Karin Reiss, Jorge Reyes, Tsiky Harivelo Robison, António Carmona Rodrigues, Mathis Rogner, João Russo, Vladimir Russo, Jorge Saaverda, Soussou Sambou, Alberto Sánchez, Saso Santl, Karine Sargsyan, Vahan Sargsyan, Martin Scarone, Öztürk Selvitop, Jorge Servert, Shamsuddin Shahid, Davit Sharikadze, Mahender Sharma, Stafford W. Sheehan, M. Hady Sherif, Manish Shrestha, Sangam Shrestha, Mundia Simainga, Martin Sinjala, Jeremie Sinzinkayo, Seming Skau, Nicolae Soloviov, Paradis Someth, Amine Boudghene Stambouli, Phillip Stovold, Samiha Tahseen, Ibrahim Ragab Mohamed Teaima, Pierre Kenol Thys, Anastasiya Timashenok, Mikael Togeby, Ernesto Torres, Philbert Tuyisenge, Alexander Urbanovich, Katalin Varga, Petro Vas'ko, Akhomdeth Vongsay, Harsha Wickramasinghe, Horace Williams, Mark Williams, Kassius Klei Ximenes, Rabiou Hassane Yari.

Introduction

Energy remains one of the most critical economic, environmental and development issues facing the world today with some 1.06 billion people—about 13 per cent of the world's population, predominantly in rural areas—still lacking access to electricity. Access to reliable and affordable electricity has an immediate and transformative impact on quality of life, access to basic services (e.g., healthcare, education) and livelihoods. Renewable energy is a key building block towards the broader development goals associated with environmental sustainability, delivery of public services and poverty eradication.

In both developing and developed countries the need for clean and sustainable sources of energy is growing more acute in the face of climate change. As the lowest cost renewable energy technology, hydropower remains at the centre of international efforts to fight climate change and transition to a clean energy future. Small hydropower (SHP) is an integral part of a broader strategy to promote development whilst reducing greenhouse gas emissions and promoting greater energy independence, as It is especially suitable for remote rural areas with a low density of energy demand due to its adaptability to the particular community's needs and local conditions. Furthermore, SHP projects, if effectively and sensitively planned, provide a rich opportunity for the empowerment of women and girls and progress towards gender equality by reducing women's labour, increasing their productivity and empowering them economically.

In order to more effectively promote SHP as a renewable and rural energy solution and overcome existing barriers, it is essential to identify the development status of the technology in different regions of the world and engage stakeholders to share existing information and accumulated experiences. Prior to the first edition of the *World Small Hydropower Development Report (WSHPDR)* published in 2013, it was clear that a comprehensive reference publication for decision makers, stakeholders and potential investors was needed to more effectively promote SHP as a sustainable renewable energy solution and to overcome the existing barriers to the spread of the technology. So far, the *WSHPDR* is the only report and knowledge platform dedicated to the dissemination of in-depth information on SHP development.

For the third time, UNIDO and ICSHP, as the global SHP knowledge leaders, are continuing their partnership for the new edition of the report, the *WSHPDR 2019*, which contains 20 regional and 166 country chapters. The *WSHPDR 2019* is the result of an enormous collaborative effort between the United Nations Industrial Development Organization (UNIDO), the International Center on Small Hydro Power (ICSHP) and over 230 local and regional SHP experts, engineers, academics and government officials from across the globe. The current edition of the Report aims not only to provide an update, but also to greatly expand on the first two editions by providing improvements in data accuracy with enhanced analysis and a more comprehensive overview of the policy landscapes compiled from a larger number of countries.

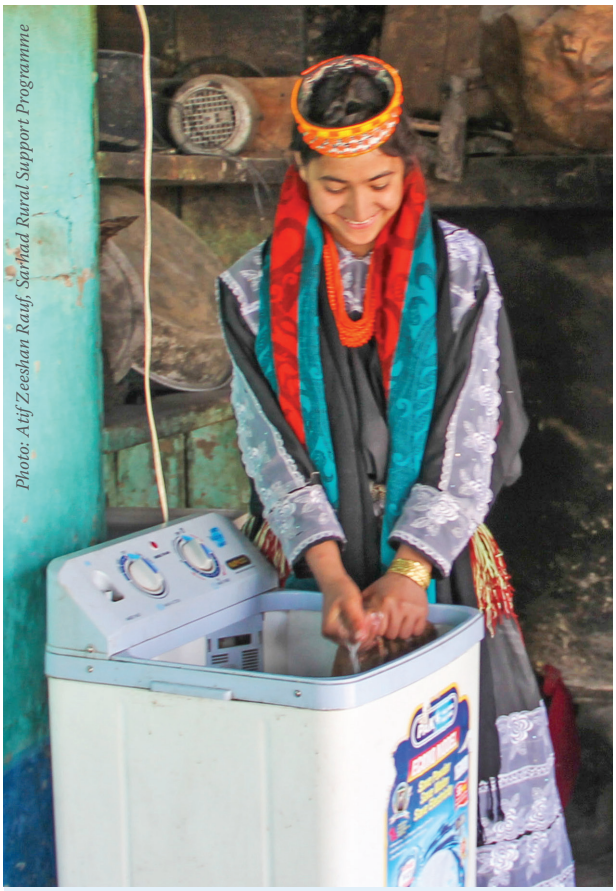


Photo: Atif Zeeshan Rauf, Sarhad Rural Support Programme

SMALL HYDROPOWER FOR PRODUCTIVE USE: the WSHPDR 2019 case study

"Following the establishment of SHPs in remote communities, marginalized people like this Kalaash girl has more opportunities to use electrical appliances. This contributes to a reduction in domestic workload for many women and girls, freeing up time for educational or economic activities. It also contributes to productive use, as some Kalaash women set up small businesses of washing clothes from home."

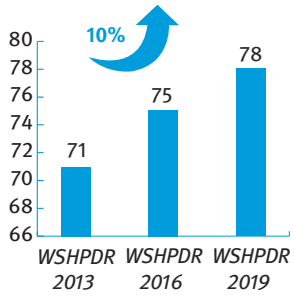
Global overview

According to the *WSHPDR 2019*, the global installed SHP capacity for plants up to 10 MW is estimated at 78 GW, indicating an increase of approximately 10 per cent compared to data from the *WSHPDR 2013* and 4.7 per cent since the *WSHPDR 2016* (Figure 1). Furthermore, since the *WSHPDR 2013* discovered SHP potential has increased by a notable 30 per cent (Figure 2). The greatest increase in installed SHP capacity is reported for Asia and Europe with 5.2 per cent each. The Americas have experienced a slight decrease due to updated information for SHP up to 10 MW, while in Oceania the decrease is due to updates and natural catastrophes. Africa experienced only a 1.5 per cent increase compared to the previous edition of the report (Figure 3). Despite the appeal and benefits of SHP solutions, much of the world's SHP potential remains untapped (66 per cent).

SHP represents approximately 1.5 per cent of the world's total electricity installed capacity, 4.5 per cent of the total renewable energy capacity and 7.5 per cent (< 10 MW) of the total hydropower capacity. Asia continues to have the largest installed capacity and potential for SHP up to 10 MW (Figure 4). Europe has the highest percentage of SHP development, with Western Europe having 85 per cent of its potential already developed (followed by Eastern Asia with 61 per cent developed) (Figure 6). In the Americas, most of the SHP is concentrated in the Northern America and South America regions.

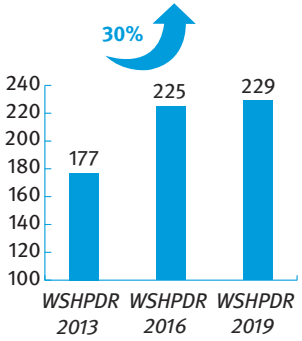
China continues to dominate the global SHP landscape. With 54 per cent of the world's total installed capacity (definition of up to 10 MW) and approximately 28 per cent of the world's total SHP potential, China has more than four times the SHP installed capacity of Italy, Japan, Norway and the United States of America (USA) combined. Together, the top five countries –China, the USA, Japan, Italy, Norway and Turkey account for 67 per cent of the world's total installed capacity of SHP.

Figure 1.
World SHP installed capacity (GW)



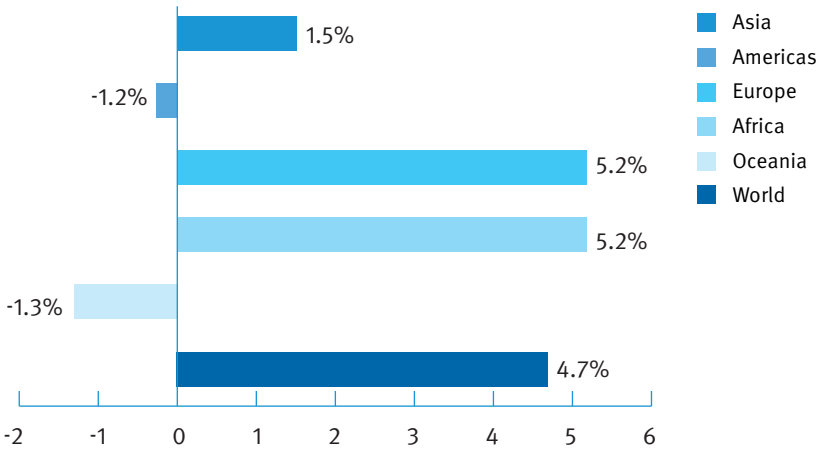
Note: SHP up to 10 MW.

Figure 2.
World SHP potential capacity (GW)



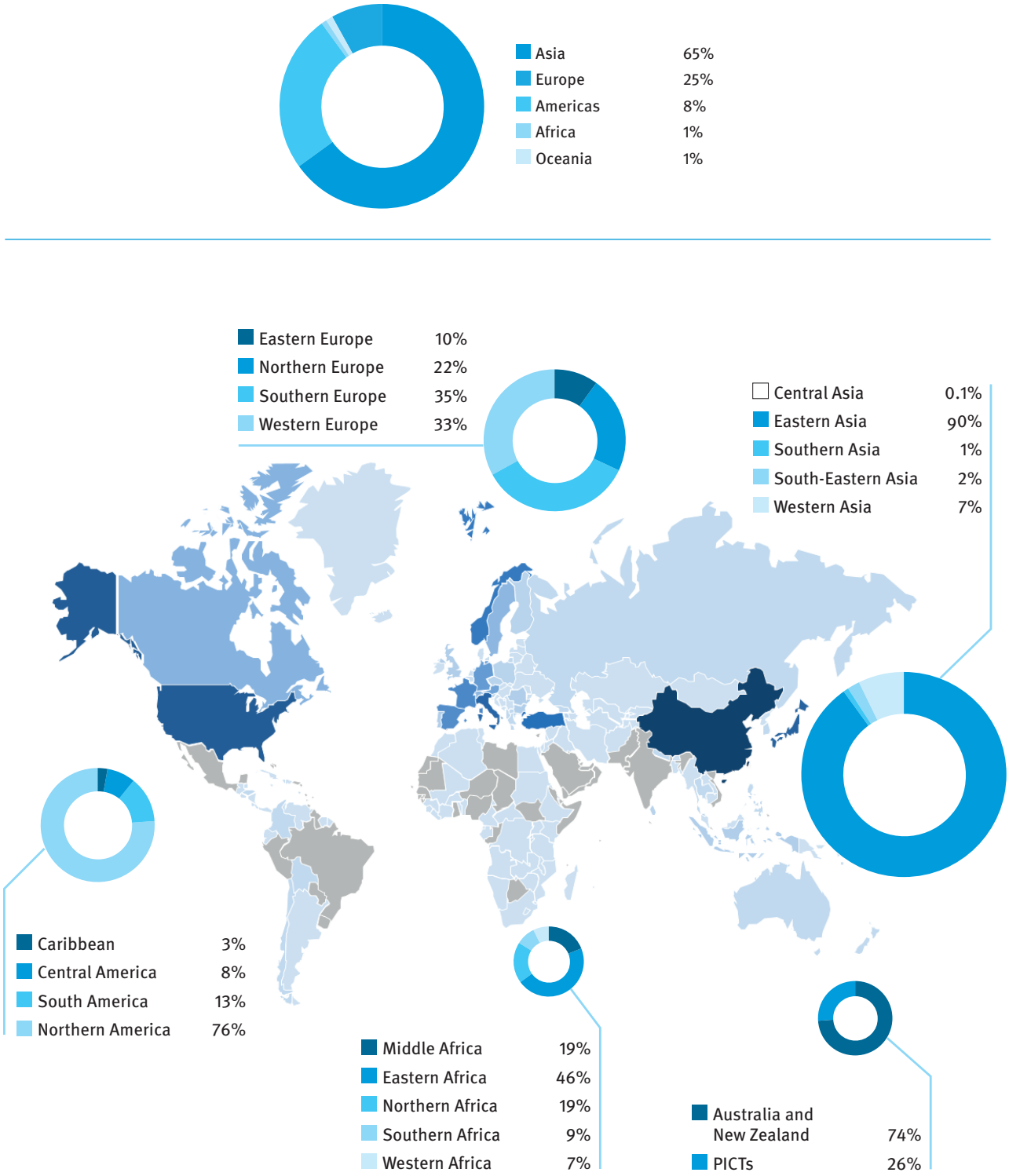
Note: SHP up to 10 MW.

Figure 3.
Installed SHP capacity change for *WSHPDR 2016 - 2019* by region (GW)



Source: WSHPDR 2019

Figure 4.
Installed SHP capacities up to 10 MW by region



Source: *WSHPDR 2019*

Note: SHP up to 10 MW. Countries without available data on SHP up to 10 MW are not included and highlighted in grey.

Figure 5.
Identified total SHP potential up to 10 MW by region

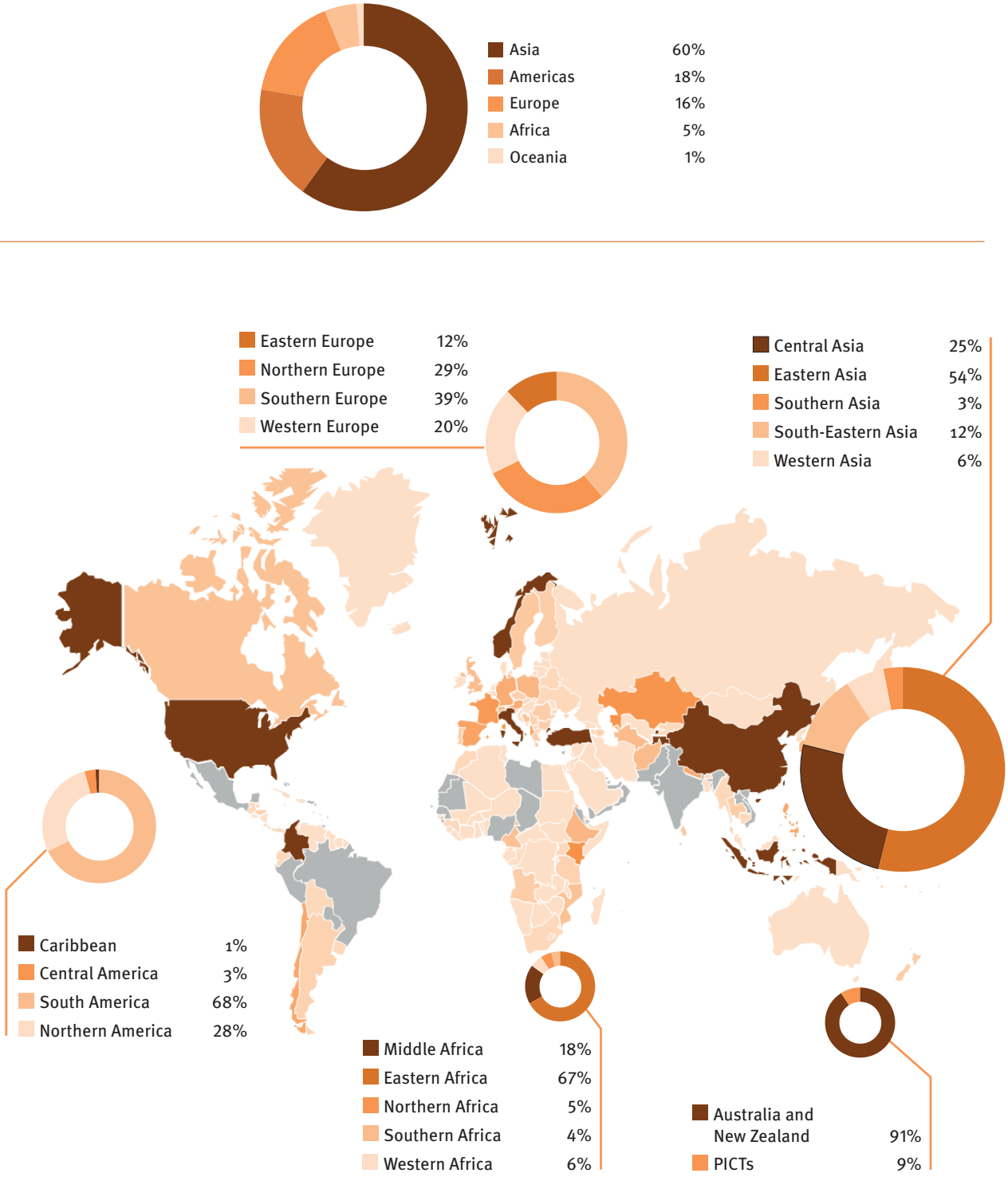
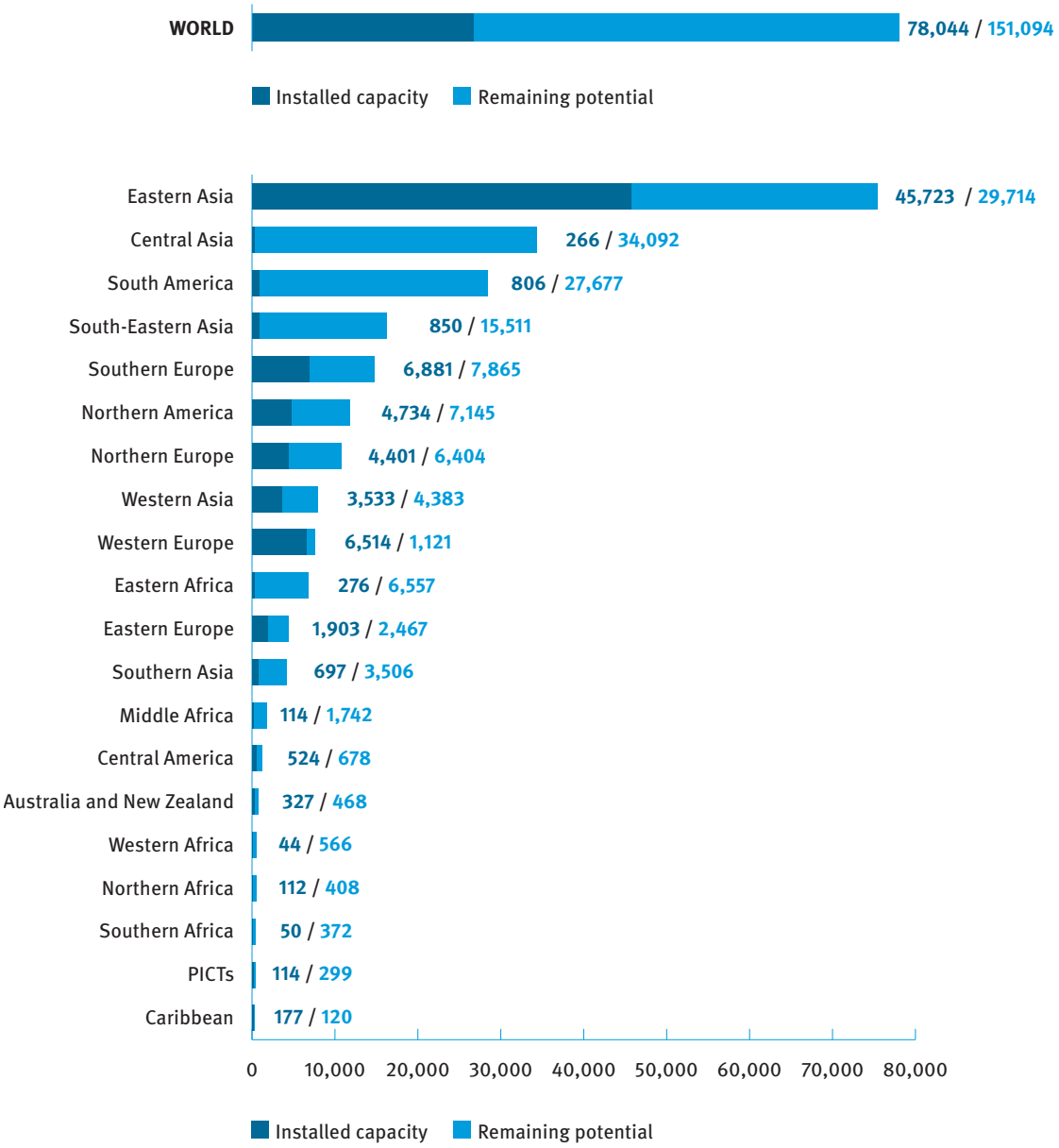


Figure 6.
Remaining SHP potential by region (MW)



Africa

SHP in Africa can be characterized as having a relatively low level of installed capacity but with considerable potential for development. Climatic and topographic characteristics vary tremendously, resulting in a large variance in SHP potential in the north and south as compared to the east and west of the continent. The total installed capacity of SHP up to 10 MW in Africa is 595 MW and the total estimated potential is 10,240 MW. This indicates that only approximately 6 per cent has so far been developed.

Eastern Africa has the highest installed capacity and potential for SHP on the continent, followed by the Western and Middle Africa regions. Northern Africa has the highest electrification rate, but, due to climatic conditions, it has low potential for hydropower. Southern Africa has the lowest installed capacity, the vast majority of which is located in South Africa. Of the 48 countries in the region, many have some form of renewable energy policy, while eight countries have established FITs relating to SHP.

Americas

Northern America and South America dominate the SHP landscape in all of the Americas through Brazil, Canada and the United States of America, with these three countries having extensive installed and potential SHP capacities. Countries in the Caribbean and Central America regions, with the exception of Mexico, have significantly smaller estimated potential. However, it is likely that further studies could reveal greater potential in the Caribbean and Central America.

The total SHP capacity in the Americas is 6,240 MW, while the total estimated potential is at 41,860 MW for SHP up to 10 MW. Some countries with enormous expected SHP potential have not performed feasibility studies to determine their exact potential capacity. Mexico, for example, is a country that is suspected to have significant SHP potential but no studies have been conducted yet. According to the available data, at least 15 per cent of the SHP potential capacity has been developed in the Americas. Many of the countries in the four regions of the Americas have also established policies that incentivize the SHP sector. Of the 30 countries in the region, three have established FITs relating to SHP either on the national or regional level—Canada, the United States of America and Ecuador.

Asia

asia has vast SHP resources that are, however, unevenly distributed across the continent. The total installed SHP capacity of Asia is 51,069 MW and the total estimated potential is 138,226 MW (for SHP up to 10 MW). This indicates that approximately 37 per cent has so far been developed.

The continent's installed SHP capacity has been increasing over the past few years. China dominates not only the Asian SHP landscape but also that of the whole world. Globally, China accounts for approximately 54 per cent of the installed SHP capacity and 28 per cent of the total potential capacity. SHP development is one of the major priorities for countries in Asia. The key motives for SHP development in the content are to decrease dependence on fossil fuels, thus mitigating environmental problems; decrease dependence on energy imports; and improve access to electricity, especially in rural areas. Of the 37 countries of the continent covered in this Report, many have some form of renewable energy policy while 16 have established FITs related to SHP.

Europe

europe has a long history of SHP development, which has enabled it to reach a high level of installed capacity. With a wide variety of climates and landscapes in the continent, SHP potential varies across the regions. Europe has the largest number of countries with established FITs for SHP—22 out of the 39 countries included in this Report already have FITs incorporated into their respective SHP policies.

The overall installed capacity in the region is 19,699 MW, while the potential capacity is estimated at 37,554 MW. In comparison to the *WSHPDR 2013*, this represents an increase in installed capacity of 10 per cent (5 per cent in caparison to the *WSHPDR 2016*). As of 2019, Europe has developed nearly 52 per cent of its SHP potential, with Western Europe reaching the world's highest SHP development level of 85 per cent. The greatest remaining potential lies in Southern Europe, which is estimated at 7,865 MW.

Oceania

oceania is the smallest region in terms of the number of countries included in this Report as well as in terms of installed and potential SHP capacity. The total installed capacity amounts to 441 MW, indicating an increase of 7 per cent in comparison to the *WSHPDR 2013*. The total estimated potential is 1,208 MW. The installed capacity and the newly assessed potential capacity indicate that approximately 37 per cent has so far been developed. Of the 10 countries of the region covered in this report, only some regional governments in Australia have established FITs relating to SHP.

The Oceania region is very diverse in terms of SHP potential. While all the countries receive enough rainfall to merit constant SHP production, only a few of the islands have mountainous terrain, which is usually a key factor for SHP potential. The Australia and New Zealand region, which is found in the southernmost part of Oceania, is the richest area in regard to SHP potential, while the Pacific Island Countries and Territories (PICTs) are mostly flat islands and have little or no SHP potential. As a result, the greatest barrier for SHP development in Oceania is the topography.

Case studies

The case study section is a new addition to the WSHPDR. It is comprised of 18 case studies of successful SHP implementation in a range of communities. The case studies add a more detailed, practical perspective on the transformative potential of SHP and the best practices. Case studies give specific examples of communities that are using SHP for productive purposes to meet their needs and improve quality of life. The purpose of this new section is to provide easy access to the learnings drawn from such experience, thus forming a knowledge base that can benefit communities, decision-makers and developers elsewhere.

The cases demonstrate how reliable access to electricity provided by SHP revolutionizes daily life in communities worldwide, particularly in rural areas, creating employment opportunities, stimulating economic development, strengthening the capacity of existing infrastructure and local institutions, while minimizing negative environmental impacts. The following five aspects of SHP development are covered in the case studies.

SHP for productive use.

While lack of access to electricity holds back economic development, SHP can create new opportunities for local businesses by providing power infrastructure, as demonstrated by the examples of 165 SHP projects developed under the Sarhad Rural Support Programme in Pakistan and the Gura SHP developed by the Kenya Tea Development Agency in Kenya. In these cases, reliable access to electricity through SHP allowed local enterprises to expand and create new business opportunities through greater efficiency and productivity, and reduced costs.

SHP for social and community development.

Lack of electricity also constitutes a significant barrier to human, social and community development, specifically impacting vulnerable groups, including women and young people. The examples of SHP projects in the Dominican Republic, Nicaragua, Zambia, Tajikistan, Japan, the Democratic Republic of the Congo and China demonstrate that SHP can create conditions for communities to improve their quality of life, create employment, increase the standard of public service provision, improve overall health and education and achieve greater autonomy, even in areas affected by armed conflicts.

SHP financing.

Access to financial resources is one of the most common barriers to SHP development across countries due to the high upfront investment required to launch a project. It is often the case that local banks' ability to support SHP projects is constrained by single- borrower exposure limits imposed by central banks, with their own internal guidelines being predominantly based on collateral borrowing. However, innovative mechanisms have been developed by some international and local banks to support projects such as SHPs. The Risk Sharing Framework of the European Bank for Reconstruction and Development offers local partner banks funded or unfunded risk-participation schemes, which, for example, supported the development of the Akmeta SHP in Georgia. Ping An Bank, a commercial Chinese bank, offers customized financial assistance for SHP construction and operation in poverty-stricken areas of the country.

Technology, innovation and smart SHP.

SHP development can also be restricted due to a lack of suitable sites, in particular when the most attractive potential has already been harnessed or when strict environmental or other regulations limit further development in areas with available potential. However, as the case studies demonstrate, a range of technical solutions exist that can help adapt the technology to local regulations and bring it to more communities. These include using existing hydro-technological infrastructure for the installation of an SHP, as in the case of the Zagrody SHP in Poland; the innovative fish lift sluice system developed by Der Wasserwirt; the Turbulent turbines which allow harnessing the potential of low head streams; and hydrokinetic turbines developed by Smart Hydro Power that can be installed in rivers, but also in existing infrastructure such as canals or water regulation dams.

Incentive policies for SHP development.

Another common barrier to SHP development is the lack of a regulatory framework that would encourage the use of SHP and make the sector more attractive for investment. The example of Panama demonstrates how SHP development can accelerate with the support of appropriate incentive policies.

Green SHP.

Unregulated SHP development can result in significant ecological impacts, including river loss of water, changed river ecology, reduced river connectivity and affected migratory fish and other aquatic species. To maintain the ecological safety of the sector, the future of SHP development should be in the form of green SHP, supported by regulations, guidelines, incentive policies and practices. Two case studies outline the measures taken in China and Austria to promote SHP construction and rehabilitation in line with the principles of ecological sustainability.

Conclusions & Recommendations

SHP is a mature and versatile technology, effective for providing access to clean and sustainable electricity both in the developing and developed world, particularly in rural areas. Through developing SHP, many countries have already taken steps—or are beginning to take steps— to alleviate poverty and increase access to electricity. SHP also helps developed nations achieve targets for advancing renewable energy and reducing greenhouse gas emissions.

The purpose of this Report is to illustrate the improvements achieved in the SHP sector across regions and the great positive impacts linked to SHP development. Since the publication of the first edition of the Report in 2013, the combined installed capacity of SHP in the world increased by 10 per cent reaching 78 GW. At the same time known SHP potential increased by 30 per cent to 229 GW. Thus, the data collected in the Report demonstrate that there is still room for improvement for the SHP sector in many parts of the world, with such regions as Eastern Europe, Central Asia and South America possessing around 30 GW of untapped SHP potential each. Overall, despite the progress made in SHP development in the last few years, many of the barriers and, hence, recommendations for the further development of the sector remain similar to those listed in the previous editions of the Report.

The following recommendations for addressing the barriers to SHP development are provided as general recommendations and should not be considered as comprehensive.

1. Undertake detailed resource assessments

Developing countries should undertake detailed analyses of their SHP potential in order to lower the development costs and encourage private investment. Developed countries should similarly undertake detailed re-assessments of their SHP potential accounting for new technologies, ecological conditions, regulations as well as the potential arising from the conversion of existing infrastructure and the rehabilitation of old sites.

2. Develop appropriate policies and regulations

Policies and financial incentives already established for other sources of renewable energy should be extended to cover SHP, particularly emphasizing green technology, and clear targets for SHP development should be set. Such policies and incentives should be properly designed to account for the local conditions and draw on a collaboration among agencies responsible for water resources, environment and electricity. Government agencies should also streamline the licensing process by creating a one-stop shop for standardized permits and contracts.

3. Facilitate access to sustainable sources of financing

An overall strategy aiming to reduce the financial risks for investors should be developed. High initial costs need to be overcome with easier and improved access in order for project developers to be able to successfully provide finance. One measure that can mitigate this is creating awareness of SHP among local banking institutions or microfinance institutions in order to improve the risk assessment and provide conducive loan conditions.

4. Facilitate access of the SHP industry to equipment and technology

Building or improving industries that serve as components to SHP will aid in the overall development of the SHP sector. In countries with insufficient local technology, access to foreign imports can be aided through the establishment of concessionary duties and reduced import taxes.

5. Provide reliable infrastructure

Developing robust grids with suitable capacity and coverage to accommodate new connections facilitates connecting SHP plants and is critical for attracting private investment. In countries with high distribution losses, investments in distribution systems should match those in generation, in order to raise overall efficiency of SHP projects. Establishing micro-grids with SHP providing base-load power can also offer a short- to medium-term—or even permanent—solution for electrifying remote and inaccessible communities.

6. Improve local skills and expertise

By increasing local capacities in conducting feasibility studies, construction, and operation and maintenance of SHP plants, the whole SHP sector can become more self-sufficient and long-lasting for countries.

7. Strengthen international and regional cooperation

Promotion of SHP by international and regional institutions is essential for mainstreaming SHP as a positive renewable energy solution. On a more specific level, more information is needed on such topics as new SHP technologies, sustainable models for financing and ownership of SHP projects, the effectiveness of financial incentives for SHP development and the impact of climate change on SHP. By developing South-South cooperation and triangular cooperation among developing countries, developed countries and international organizations, international and regional agencies can facilitate the transition of individual pilot SHP projects towards the successful implementation of full-scale SHP programmes.

Attachments

Africa

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Algeria	up to 10	42.1	-	42.1	-
Angola	up to 10	13.1	600.0	13.1	600.0
Benin	up to 30	0.6	304.9	0.6	69.9
Botswana	-	-	-	0	1.0
Burkina Faso	-	-	-	2.3	17.0
Burundi	up to 1	3.1	30.5	15.8	61.0
Cameroon	up to 10	1.0	970.0	1.0	970.0
Central African Republic	up to 10	28.8	41.0	28.8	41.0
Congo	-	-	-	0	65.0
Côte d'Ivoire	up to 10	5.0	45.7	5.0	45.7
Democratic Republic of the Congo	up to 10	56.0	101.0	56.0	101
Egypt	-	-	-	6.8	51.7
Equatorial Guinea	-	-	-	7.5	-
Eswatini	-	-	-	8.2	16.2
Ethiopia	up to 10	12.9	1,500	12.9	1,500
Gabon	-	-	-	4.6	7.8
Gambia	up to 30	0	-	0	12.0
Ghana	up to 1	0	12.1	0	17.4
Guinea	-	-	-	10.8	198.0
Kenya	up to 10	39.4	3,000	39.4	3,000
Lesotho	up to 10	3.8	38.2	3.8	38.2
Liberia	up to 30	4.9	85.9	4.9	56.4
Madagascar	-	-	-	33.0	82.0
Malawi	up to 5	5.6	150.0	-	-
Mali	up to 30	5.7	61.7	5.7	28.4
Mauritania	-	-	-	0	-
Mauritius	-	-	-	19.3	19.7
Morocco	up to 10	38.4	306.6	38.4	306.6
Mozambique	up to 25	19.4	N/A	3.4	1,000
Namibia	-	-	-	0.05	120.0
Niger	-	-	-	0	8.0
Nigeria	up to 30	64.2	735.0	-	-
Réunion	up to 10	11.0	17.0	11.0	17.0
Rwanda	up to 5	24.8	111.1	-	-
Sao Tome and Principe	up to 10	2.7	63.8	2.7	63.8
Senegal	up to 10	0	-	0	-
Sierra Leone	up to 30	12.9	639.0	12.9	-
Somalia	-	-	-	0	4.6
South Africa	up to 40	-	-	38.0	247.0
South Sudan	-	-	-	0	24.7
Sudan	up to 5	7.2	63.2	7.2	-
Tanzania	up to 10	30.4	480.0	30.4	480.0
Togo	-	-	-	1.6	144.0
Tunisia	-	-	-	17.0	56.0
Uganda	up to 20	82.8	258	51.8	200.0
Zambia	up to 20	39.7	138.7	12.9	62.0
Zimbabwe	up to 30	30.2	-	15.2	120.0

Americas

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Argentina	up to 50	410.2	-	97.0	430.0
Belize	-	-	-	10.3	21.7
Bolivia	up to 5	-	-	152.8	200.0
Brazil	up to 30	5,670	20,506	-	-
Canada	up to 50	3,400	15,000	1,113	-
Chile	up to 20	488.0	10,825	236.0	2,113
Colombia	up to 10	214.0	25,000	214.0	25,000
Costa Rica	-	-	-	125.5	-
Cuba	-	28.9	84.9	28.9	84.9
Dominica	up to 10	4.8	4.8	4.8	4.8
Dominican Republic	up to 10	59.3	59.3	59.3	59.3
Ecuador	up to 10	98.2	296.6	98.2	296.6
El Salvador	up to 20	42.0	158.0	22.6	119.8
French Guiana	up to 10	6.3	-	6.3	-
Greenland	up to 10	8.8	183.1	8.8	183.1
Grenada	-	0	7.0	0	7.0
Guadeloupe	up to 10	11.1	16.1	11.1	16.1
Guatemala	up to 5	114.3	201.0	-	-
Guyana	up to 5	0	24.2	0	92.1
Haiti	up to 10	7.0	20.9	7.0	20.9
Honduras	up to 30	301.8	-	128.0	385.0
Jamaica	up to 10	16.6	45.5	16.6	45.5
Mexico	up to 30	699.3	-	-	-
Nicaragua	up to 10	18.6	85.7	18.6	85.7
Panama	up to 20	213.5	417	104.8	263.3
Paraguay	up to 50	0	116.3	0	86.3
Peru	up to 20	363.0	1,600	-	-
Puerto Rico	up to 10	41.8	47.9	41.8	47.9
Saint Lucia	-	0	2.7	0	2.7
Saint Vincent and the Grenadines	up to 10	7.0	7.4	7.0	7.4
Suriname	-	-	-	1.0	2.7
Uruguay	up to 50	0	232.0	0	207.8
USA	-	-	-	3,612	10,583
Venezuela	-	-	-	0.3	48.0

Asia

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Afghanistan	up to 10	75.7	1,200	75.7	1,200
Armenia	up to 30	353.0	422.0	327.8	-
Azerbaijan	up to 10	26.0	520.0	26.0	520.0
Bangladesh	-	-	-	0.06	59.5
Bhutan	up to 25	32.1	17,792	8.1	8.1
Cambodia	up to 10	1.7	300.0	1.7	300.0
China	up to 50	79,300	128,000	41,900	63,500
DPRK	-	-	-	83.2	-
Georgia	up to 13	178.0	335.5	142.3	187.4
India	up to 25	4,485	21,134	-	-
Indonesia	up to 10	403.0	12,800	403.0	12,800
Iran	up to 10	19.5	102.5	19.5	102.5

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Iraq	-	-	-	6.0	26.4
Israel	-	-	-	6.0	-
Japan	up to 10	3,545	10,327	3,545	10,327
Jordan	up to 10	12.0	58.2	12.0	58.2
Kazakhstan	up to 35	200.3	4,800	116.0	2,707.0
Kyrgyzstan	up to 30	46.6	409.0	46.6	275.0
Laos	up to 15	148.1	2,287	50.4	-
Lebanon	up to 10	31.0	140.0	31.0	140.0
Malaysia	-	-	-	39.5	-
Mongolia	up to 10	5.22	27.0	5.22	27.0
Myanmar	-	-	-	36.4	231.0
Nepal	up to 25	446.8	4,196.2	236.2	1,959.5
Pakistan	up to 50	410.0	3,100	-	-
Philippines	up to 10	147.0	2,021.0	147.0	2,021
ROK	up to 10	189.7	1,500	189.7	1,500
Saudi Arabia	-	-	-	0	130.0
Sri Lanka	up to 10	357.0	873.0	357.0	873.0
Syria	up to 10	20.8	-	20.8	-
Tajikistan	up to 30	-	-	26.6	30,000
Thailand	up to 6	172.0	700.0	-	-
Timor-Leste	up to 50	0.35	-	0.35	219.8
Turkey	up to 10	2,961.3	6,500	2,961.3	6,500
Turkmenistan	-	-	-	1.2	1,300
Uzbekistan	up to 30	262.0	1,391.8	75.8	75.8
Viet Nam	up to 30	1,665.8	7,200	-	-

Europe

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Albania	up to 15	330.2	-	240.2	1,963
Austria	up to 10	1,523	1,780	1,523	1,780
Belarus	up to 10	18.0	250.0	18.0	250.0
Belgium	up to 10	72.8	103.4	72.8	103.4
Bosnia and Herzegovina	up to 10	90.0	1,005	90.0	1,005
Bulgaria	up to 1	-	-	486.0	580.7
Croatia	up to 10	33.0	192.0	33.0	192.0
Czech Republic	up to 10	337.0	465.0	337.0	465.0
Denmark	up to 10	9.8	9.8	9.8	9.8
Estonia	up to 10	6.5	10.0	6.5	10.0
Finland	up to 10	312.0	600.0	312.0	600.0
France	up to 10	2,200	2,615	2,200	2,615
Germany	up to 1	-	-	1,731	1,830
Greece	up to 15	232.0	2,000	232.0	600.0
Hungary	up to 5	16.5	55.0	-	-
Iceland	up to 10	54.8	-	54.8	-
Ireland	up to 5	-	-	41.0	60.0
Italy	up to 10	3,395	7,073	3,395	7,073
Latvia	up to 10	28.0	75.0	28.0	75.0
Lithuania	up to 10	26.9	51.9	26.9	51.9
Luxembourg	up to 10	34.0	44.0	34.0	44.0
Moldova	up to 10	0.4	3.0	0.4	3.0

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Montenegro	up to 10	25.3	97.5	25.3	97.5
Netherlands	up to 10	3.0	12.0	3.0	12.0
North Macedonia	up to 10	130.0	260.0	130.0	260.0
Norway	up to 10	2,571	7,803	2,571	7,803
Poland	-	-	-	294.8	1,500
Portugal	up to 10	414.0	750.0	414.0	750.0
Romania	up to 10	404.0	730.0	404.0	730.0
Russia	up to 30	826.5	825,845	169.6	-
Serbia	up to 30	87.6	-	87.6	467.2
Slovakia	up to 10	81.6	241.4	81.6	241.4
Slovenia	up to 10	155.0	180.0	155.0	180.0
Spain	up to 10	2,079	2,158	2,079	2,158
Sweden	up to 10	961.0	-	961.0	-
Switzerland	up to 10	950.0	1,250	950.0	1,250
UK	up to 10	390.0	1,179	390.0	1,179
Ukraine	up to 10	95.0	375.0	95.0	375.0

Oceania

Country	*Local SHP definition*	*Installed capacity (local def.)*	*Potential capacity (local def.)*	*Installed (<10 MW)*	*Potential (<10 MW)*
Australia	up to 10	173.0	-	173.0	-
New Zealand	up to 10	154.0	622.0	154.0	622.0
Fiji	-	11.2	14.0	11.2	14.0
New Caledonia	up to 10	9.9	100.0	9.9	100.0
Papua New Guinea	up to 10	29.1	153.0	29.1	153.0
Solomon Islands	up to 10	0.3	11.0	0.3	11.0
Vanuatu	up to 10	1.3	6.0	1.3	6.0
Federated States of Micronesia	-	0.7	9.0	0.7	9.0
French Polynesia	up to 10	48.4	98.0	48.4	98.0
Samoa	-	13.5	22.0	13.5	22.0

Contributing organizations

Laboratoire de Génie Électrique d'Oran (LGEO)

Université des sciences et de la technologie d'Oran – Mohamed Boudiaf (USTO-MB)

Guakía Ambiente

Scientific Research Institute of Energy (SRIE)

Kleinwasserkraft Österreich

Pöyry

Jimma University

France Hydro Électricité

Ea Energy Analyses

Guyana Energy Agency (GEA)

La Asociación Hondureña de Energía Renovable (AHER)

The International Energy Agency Technology Cooperation Programme on Hydropower (IEA Hydro)

International Network on Small Hydro Power (INSHP)

Komite Nasional Indonesia untuk Bendungan Besar (KNI-BB) / National Committee on Large Dams (INACOLD)

Catalytic Innovations

Ministère de l'Energie, de l'Eau et des Hydrocarbures (MEEH) de Madagascar

Universiti Kuala Lumpur (UniKL)

University of Mauritius

Agenția pentru Eficiență Energetică (AEE) / Agency for Energy Efficiency, Moldova

Universidade Eduardo Mondlane

IHE Delft Institute for Water Education

Asociacion de Trabajadores de Desarrollo Rural – Benjamin Linder (ATDER-BL)

The European Bank for Reconstruction and Development (EBRD)

Energetyka Wodna

Hangzhou Regional Center (Asia-Pacific) for Small Hydro Power (HRC)

Der Wasserwirt

Ping An Bank

Sarhad Rural Support Programme (SRSP)

Smart Hydro Power

La Organización Latinoamericana de Energía (OLADE)

SMEC - Engineering General Consultants EGC (Pvt) Ltd.

Centro de Investigaciones Hidráulicas e Hidrotécnicas (CIHH)

Universidad Tecnológica de Panamá (UTP)

Towarzystwo Rozwoju Małych Elektrowni Wodnych (TRMEW)

Faculdade de Ciências e Tecnologia (FCT), Universidade Nova de Lisboa

Programa de Pequeños Subsidios (SGP) del FMAM República Dominicana

Université Cheikh Anta Diop de Dakar (UCAD)

Slovak University of Technology in Bratislava (STU) - Faculty of Electrical Engineering and Information Technology (FEI)

One Earth Future Foundation

Sri Lanka Sustainable Energy Authority (SLSEA)

Sudan Energy Research Institute (ERI)

École Polytechnique Fédérale de Lausanne (EPFL)

University of Dar es Salaam (UDSM)

Faculté des Sciences Economiques et de Gestion de Sfax (FSEGS)

Kocaeli Üniversitesi

NEWPLAN Group Ltd

Institute of Renewable Energy of the National Academy the Sciences of Ukraine

The Economic Community of West African States (ECOWAS) Centre for Renewable Energy and Energy Efficiency (ECREEE)

Zhaoheng Hydropower Group

HYCON GmbH

Turbulent

Virunga Power

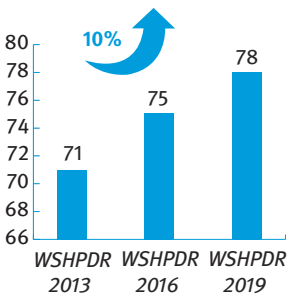
Universidad de Murcia

Platform of Hydraulic Constructions (PL-LCH)

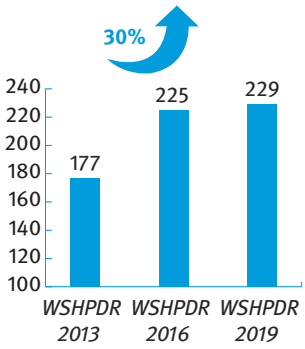
World Small Hydropower Development Report 2019

The ***World Small Hydropower Development Report (WSHPDR) 2019*** is an update of the Report's first two editions in 2013 and 2016. The *WSHPDR 2019* contains 166 national reports and 20 regional reports, with 21 new countries added since the first edition.

World SHP installed capacity (GW)



World SHP potential (GW)



- The Report is available on **www.smallhydroworld.org;**
- More than 230 experts and organizations have been involved;
- The Report covers **20 regions and 166 countries**;
- Every country report provides information on:
  a) Electricity sector;
  b) Small hydropower sector;
  c) Renewable energy policy and;
  d) Barriers to small hydropower development.

A special report with **Case Studies** is added to the *WSHPDR 2019*, showing the different roles small hydropower can play in achieving the SDGs.

Small hydropower for a better world

- SHP for productive use;
- SHP for social and community development;
- SHP financing;
- Technology, innovation and smart SHP;
- Incentive policies for SHP development;
- Green SHP.

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna International Centre
P.O. Box 300 · 1400 Vienna · Austria
Tel.: (+43-1) 26026-0
E-mail: renewables@unido.org
www.unido.org

INTERNATIONAL CENTER ON SMALL HYDROPOWER

136 Nanshan Road
Hangzhou · 310002 · P.R.China
Tel.: (+86-571) 87132780
E-mail: report@icshp.org
www.icshp.org