CHAPTER 11

SINGAPORE

A Living Lab for Renewable Energy

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From launching the world's largest floating photovoltaic (PV) test bed to building the first industrial micro-grid test system in South East Asia,[1] Singapore is demonstrating that it can be a 'Living Lab' for renewable energy (RE) innovators to test ideas. Beyond testing, innovators can leverage Singapore's world-class legal framework, robust intellectual property (IP) regime, conducive business environment, and extensive global networks to commercialize their innovative RE ideas, transforming them into viable technologies for global markets.

By 2040, the world's energy demand is expected to grow substantially—by 30%.[2] Coupled with the megatrend of rapid urbanization and the ever-increasing appetite for energy, the pursuit of RE innovation is more pressing than ever before.

The year 2015 marked a milestone: global RE capacity additions exceeded those of fossil fuels and nuclear energy for the first time.[3] Nearly two-thirds of all new net power capacity additions came from renewables in 2016.[4] The confluence of these factors fuelled the global economy's increased investments in RE technologies. Bloomberg estimates that RE will attract a share of US$7.3 trillion in investments between 2016 and 2040, comprising 72% of investments in new power technologies.[5]

Against this backdrop, it has become imperative for policy makers to be kept abreast of the emerging technology trends in RE to make better-informed decisions about their energy needs.

In this chapter, the Intellectual Property Office of Singapore (IPOS) provides some useful insights for decision makers by examining global trends and emerging areas, as well as leading countries in the field of PV, through the lens of a patent landscape analysis. It then discusses, using Singapore as an example, how small nations can play an outsized role in driving RE innovation, and how IP and IP offices can complete the innovation value chain to bring technology to market.

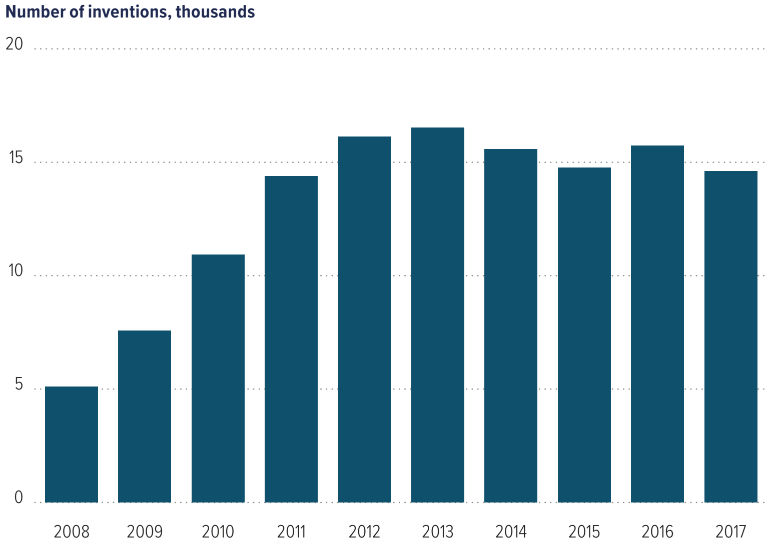
Renewable energy–related patent landscape insights

The rising interest in RE as an alternative energy source warrants a deeper look at global patenting activities in this burgeoning IP-intensive industry. The area of PV technologies is particularly interesting because, within the next 25 years, solar power is expected to become the cheapest source of new electricity generation.[6]

The Intellectual Property Office of Singapore (IPOS) commissioned its subsidiary, IPOS-International, to conduct a PV patent landscape analysis report. This chapter makes substantial reference to the results of this internal report.

Figure 1.

Publication trend of photovoltaic-related inventions, by earliest publication year

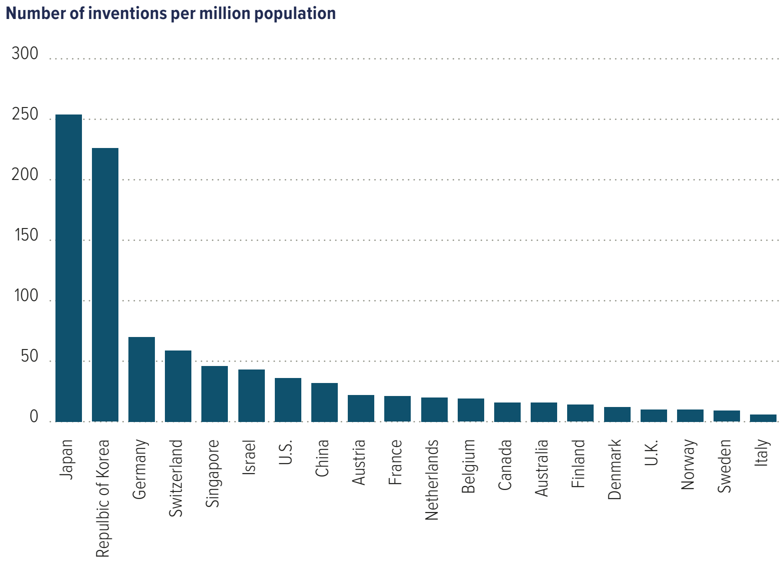


Source: IPOS-International, internal report.

Note: Data for 2017 are incomplete because (1) the cut-off of data extraction is 11 December 2017; and (2) the search string relied on patent classification codes, and some of the patent documents newly published in 2017 might not have been classified by the cut-off date and therefore were not picked up by the search.

Figure 2.

Top 20 countries with the largest number of photovoltaic-related inventions, by applicant's country of origin



Source: IPOS-International, internal report.

Based on worldwide PV-related inventions published from 2008–17 (see Box 1 on page 173), the patent landscape analysis reported that there were indeed escalated PV-related filings globally. From 2008 to 2017, there were a total of 143,403 PV-related inventions (see Figure 1), which were largely dominated by China and East Asia. In fact, the combined contributions from China, Japan, and the Republic of Korea accounted for about 60% of the worldwide PV-related patenting activities in the last decade. However, in the last five years—that is, from 2013 to 2017—a plateau in PV-related patenting activities has been observed, suggesting that PV technologies are maturing. It is noteworthy that small countries such as Switzerland, Singapore, and Israel stand out in terms of inventions per capita, to be ranked behind traditional major hubs for PV technology such as Japan and Germany (Figure 2).

Another pertinent observation from the patent landscape analysis from 2008 to 2017 is the high growth evident in areas such as PV or PV-hybrid power plants (which has seen an increase of 54.5%), management and optimization of PV systems (up 45.9%), and support structures for PV modules (up 39.9%) (Figure 3). Countries such as China and India are delving deeper into these emerging high-growth areas,[7] probably as a result of the escalating reliance on RE to meet the world's growing energy needs, the wide adoption of PV technology, and the quickly declining cost of solar power. Interest in such system-level integration and downstream applications is likely to continue given the strong annual growth that has been seen in these areas over the past five years.

The patent landscape analysis also reported a strong correlation between countries' efforts and achievements in driving PV technologies and their use of these inventions. Three distinct groups—leaders, innovators, and users—surfaced (Figure 4). These data can inform policy makers and enterprises about where the potential competitors, collaborators, and markets are. For brevity, a representative country from each category has been chosen to illustrate the focus of PV patenting activities and installations.

Figure 3.

Top 10 emerging technology sub-domains in photovoltaic (PV), 2008–17

Emerging area	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	% change per annum, 2012–16
	No. of inventions according to earliest publication year											
PV or PV-hybrid power plants	15	26	59	45	61	40	199	277	353	267	1,342	54.5
Management & optimization of PV systems	1	0	5	9	13	25	51	56	86	105	351	45.9
Support structures for PV modules	51	116	214	202	231	249	352	679	1,030	904	4,028	39.9
Monitoring or testing of PV systems	8	20	44	108	128	129	198	363	402	406	1,806	33.2
Structural details of PV modules	10	21	20	54	61	86	121	191	200	183	947	31.7
PV module components or accessories	54	103	187	231	268	207	420	614	718	735	3,537	30.6
Solar-powered lighting	47	49	85	106	103	119	136	177	197	304	1,323	16.9
Programme-control systems	1	4	11	14	22	43	27	31	49	59	261	12.7
Circuit arrangements for AC mains	67	93	162	294	378	467	550	578	635	567	3,791	12.5
Circuit arrangements for energy storage in batteries	96	116	173	252	224	303	305	303	404	365	2,541	11.8

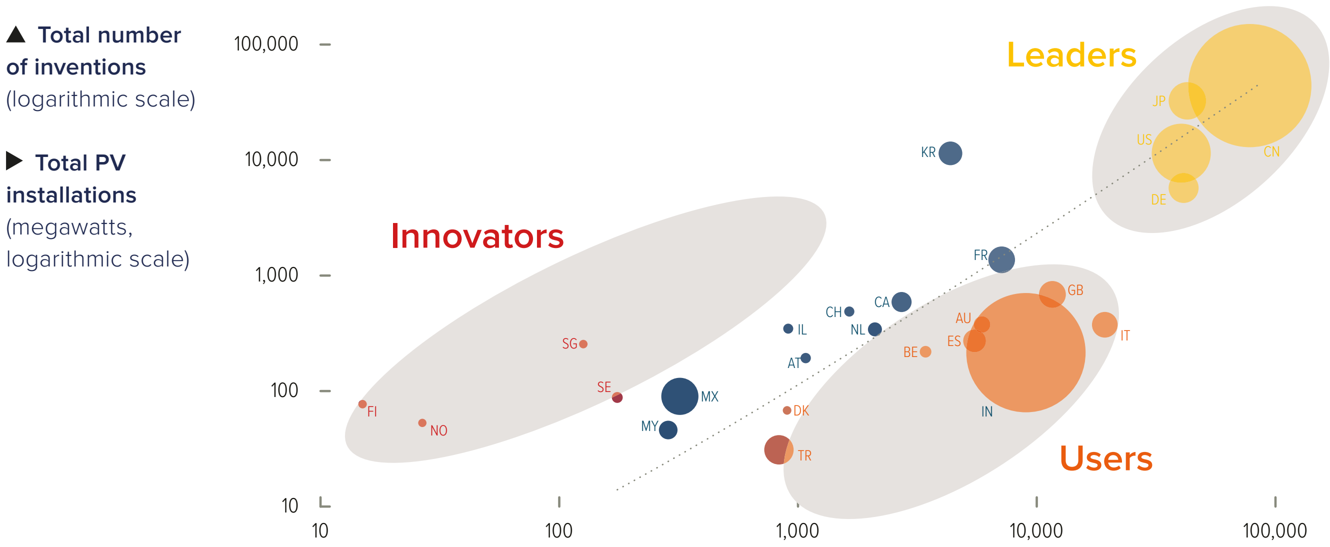
Key: 0–100 101–200 201–400 401–700 >700

Source: Source: IPOS-International, internal report.

Note: Data from 2017 are not used in the calculation of growth per annum because they are incomplete. Technology sub-domains were determined according to International Patent Classification (IPC) codes at the main group level. The IPC codes that correspond to the top 10 emerging areas are (1) H02S 10/00, (2) G06Q 10/00, (3) H02S 20/00, (4) H02S 50/00, (5) H02S 30/00, (6) H02S 40/00, (7) F21S 9/00, (8) G05B 19/00, (9) H02J 3/00, and (10) H02J 7/00. AC = alternating current.

Figure 4.

Photovoltaic (PV) technologies: Leaders, innovators, and users



Sources: UN DESA, 2017; EMA Singapore, 2016; IEA, 2016a.

Note: Bubbles are sized by population. 'Leaders' have the most PV technologies and greatest number of PV system installations; 'Innovators' have higher than average PV inventions compared to system installations (above the curve); and 'Users' have fewer than average PV inventions compared to system installations (below the curve). The trend line is a polynomial of degree 2 with intercept (R^2 = 0.8183). ISO-2 country codes: AT = Austria; AU = Australia; BE = Belgium; CA = Canada; CH = Switzerland; CN = China; DE = Germany; DK = Denmark; ES = Spain; FI = Finland; FR = France; GB = United Kingdom; IL = Israel; IN = India; IT = Italy; JP = Japan; KR = Republic of Korea; MX = Mexico; MY = Malaysia; NL = Netherlands; NO = Norway; SE = Sweden; SG = Singapore; TR = Turkey; US = United States of America.

PV technology leader: China

China's rapid expansion of PV facilities has attracted worldwide attention. It now leads the pack with close to 60,000 PV-related inventions and is the world's largest producer of solar energy, installing more than 34 gigawatts (GW) of solar capacity in 2016—more than double the figure for the United States of America (U.S.) and nearly half of the total added capacity worldwide that year.[8] A government report even suggested that, by 2050, renewables could supply 86% of the country's energy needs, with solar providing about a third of this supply.[9]

Several pro-PV government policies, along with surging global demand, have contributed to this trend. In December 2016, the National Development and Reform Commission—the country's national economic planner—announced a planned investment of US$158 billion as part of the Chinese government's bid to boost PV capacity fivefold.[10] These key fiscal policy measures have encouraged Chinese firms to forge more partnerships with research institutes and pay for technology licenses, which further spurred PV innovation in the country.

PV technology user: India

Since the 1980s, the Indian government has recognized the importance of PV systems and announced plans to bring the country's solar capacity to 100 GW by 2022.[11] This target is a fivefold increase over its previous target and represents a step-change in India's solar ambition. The International Energy Agency (IEA) projected that the country will be the second-largest producer of electricity from solar PV installations by 2040.[12]

Driven by domestic needs where peak demand is expected to exceed 285 GW by the end of 2022,[13] the Indian government has deployed PV installations rapidly through coordinated efforts with its federal institutions, such as the National Thermal Power Corporation and the Solar Energy Corporation of India, as well as its state governments. Several measures have been introduced over the last few years to incentivize and ramp up PV installations. These include waiving interstate transmission system charges and losses for both solar and wind projects, supporting domestic solar PV manufacturing facilities, and instituting appropriate measures for the smooth release of solar panel consignments imported from other countries.

PV technology innovator: Singapore

Since 2006, Singapore has pumped US$1.5 billion into R&D for the clean technology sector, which includes environment and water solutions. With the global shift in the energy sector and its inherent advantage in harnessing PV electricity, Singapore moved swiftly to invest in PV technologies to ensure an affordable, reliable, and resilient energy supply.

Singapore's interest has been focused on two areas: the management and optimization of PV systems, and the development of support structures for PV modules. In the area of management and optimization of PV systems, Singapore launched South East Asia's first industrial hybrid micro-grid test bed on the Semakau landfill in 2014 as part of the Renewable Energy Integration Demonstrator-Singapore (REIDS) initiative led by Nanyang Technological University.[14] This US$6 million hybrid micro-grid platform has since attracted waves of investment from top energy and micro-grid players—such as Accenture, DNV GL, LS Group, Schneider Electric, and Sony—to try out their technologies in Singapore.

In addition, the Energy Market Authority (EMA), the primary public agency responsible for ensuring a reliable and secure energy source for Singapore, announced in October 2017 that it will award a US$4.6 million research grant to a consortium led by the National University of Singapore to develop solar forecasting capabilities.[15] The system will make use of the growing pool of solar irradiance data as well as weather data collected by a dense island-wide network of sensors installed by Meteorological Service Singapore to improve the accuracy of PV output forecasts and grid management. The forecasting model can also be applied to other countries with similar climates and weather patterns.

Singapore successfully developed and installed 10 different floating support structures for PV systems that were constructed by both local and overseas companies on the Tengeh Reservoir in 2016 to determine the most suitable system for Singapore. Building on the results of the test bed, the Public Utilities Board (the nation's water agency) is now exploring the feasibility of deploying a 50 megawatt (MW) floating solar PV system at the Tengeh Reservoir. The amount of energy generated from such a system could potentially power about 12,500 average households in Singapore.[16]

The Singapore story: Experiment, innovate, collaborate

As evidenced by the PV patent landscape analysis, small countries with limited capacity for PV installation can still play an outsized role in the innovation of RE technologies. Singapore's model of a Living Lab to foster open innovation and public-private partnerships, as well as to allow for the rapid development, test-bedding, and deployment of RE technologies, is one example of how this can be achieved.

Singapore has invested and continues to invest heavily to drive PV research. For instance, the National Research, Innovation and Enterprise 2020 plan has specifically set aside US$660 million for R&D and deployment initiatives related to urban solutions and sustainability.[17] The funding will strengthen Singapore's innovation and research capacities in the areas of solar technologies, smart grids, and energy storage systems.

Strong governmental commitment has been instrumental in fostering the growth of numerous research bodies undertaking complementary PV research. For example, the Solar Energy Research Institute of Singapore (SERIS), set up in 2008, was one of the first research bodies to cement the country's position as a solar energy hub in Asia. And the Energy Research Institute at Nanyang Technological University (ERI@N) was set up in 2010 to study wind and marine renewable energy, energy storage, and fuel cells. The Campus for Research Excellence and Technological Enterprise (CREATE), established in 2012, focused its research in energy storage systems and brought together top international universities and research institutes to tackle global energy issues.

In addition to conducting R&D, considerable efforts are directed towards fostering partnerships between relevant government agencies and international and local energy market players to create viable PV solutions. One such partnership is the collaboration between the Singapore Institute of Technology (SIT) and the Singapore Power (SP) Group to build Singapore's first experimental urban micro-grid, which will be housed in SIT's future campus in the Punggol Digital District.[18] The micro-grid will be a national infrastructure open to the research community and businesses. The platform allows new technologies and solutions to be tested in a controlled environment, while providing students with the opportunity to work with industry partners and energy start-ups. When completed, it will be the first university in South East Asia to have a multi-energy micro-grid network.

True to its Living Lab concept, Singapore has been reaching out to researchers and companies from all over the world to experiment, to act as a test bed, and to scale up their RE solutions through Singapore. REC Solar, a subsidiary of the Norway-based REC Group—a leading global provider of solar energy solutions—will inject close to US$150 million into their production plant in Singapore, which is regarded as one of the world's largest fully integrated solar manufacturing facilities.[19] This investment will produce an output sevenfold higher than the current production of Twinpeak, a 120-cell, high-power, multi-crystalline module. The REC Group has also committed to investing another US$37 million in a research partnership with SERIS, which is one of the leading solar research institutes in the world. The collaboration will accelerate the commercialization of innovative solar technologies in Singapore.

In a recent announcement, Germany-based VDE Renewables, together with the Fraunhofer Institute for Solar Energy Systems and ERI@N, will be setting up a Global Energy Storage Competence Cluster to serve the international clean-technology sector along the entire value chain.[20] The Chinese firm Narada will also set up its regional Energy Storage Solution Centre of Excellence in Singapore to develop co-innovation opportunities with local companies.[21]

These activities have created a vibrant PV ecosystem in Singapore. Chinese companies such as GCL Poly Energy Holdings and Linyang Renewable, as well as U.S. wind company Hover Energy, together with 50 other energy market players, have all established their regional headquarters in Singapore to house their various business functions.[22]

Singapore has also nimbly turned rapid digitalization and disruptive technologies to its advantage. Through a highly coordinated policy directive, the island nation is now an accessible launch pad for energy market players to create innovative solutions. In addressing the needs of the energy market, the EMA launched a regulatory sandbox in October 2017 to enable the energy sector to test new products and services, in a creative manner, outside of Singapore's regulatory systems.[23] The sandbox complements ongoing R&D initiatives, whereby market players can tap into new technologies or apply existing technologies in novel ways to create value for electricity and gas consumers, or to improve business and operational procedures. This bold move is essential for growing new, potentially disruptive technologies that do not fit within the existing regulatory environment and infrastructure.

Successes in going to market

Singapore's approach, as illustrated through various examples in this chapter, shows that small countries can drive PV innovation through its Living Lab concept by enabling global innovators in the public and private sectors to experiment, innovate, and collaborate. This section presents two examples of successful spin-offs that have grown out of Singapore's Living Lab model.

A hybrid commercialization approach: Printed Power

In 2010, Singapore set up ERI@N at Nanyang Technology University of Singapore to focus on system-level research in the energy sector. One of their flagship programmes—the ERI@N Accelerator—was launched specifically to galvanize entrepreneurship by nurturing spin-offs that show good potential to translate R&D outcomes into viable products and services for the market. Printed Power is one successful spin-off from this research-based accelerator programme. It was created to build an integrated energy-harvesting wireless sensing device with customizable power management solutions.

For Printed Power, ERI@N management adopted a hybrid approach. An IP holding and commercial unit was set up where the key technology involved was licensed to Printed Power. The technology can potentially be sub-licensed to respective partners for market penetration. At the same time, ERI@N worked through its networks and resources to scale the business. ERI@N was involved in hiring key personnel at Printed Power and mobilized some of its key research scientists to the spin-off to build the business. Additionally, ERI@N developed a viable business plan together with Printed Power and secured early-stage seed funding of US$375million.

Printed Power is now operating as an independent entity. In the first half of 2018, it will be launching its products, which can be used in smart buildings and homes, transportation, industrial applications of Internet of Things and automation, data centres, manufacturing, precision agriculture, supply chain, and logistics industries in Singapore. There are plans to expand to other Asia Pacific countries such as China and India in the next two to three years. Printed Power has also identified Israel and the U.S. as key markets, and plans to move in there subsequently.

Solving a real-world problem: COMMLIGHT

SERIS, the Solar Energy Research Institute of Singapore, is an industry-focused research centre at the National University of Singapore, funded by the National Research Foundation through the Singapore Economic Development Board. One of its research projects was to create a high-efficiency yet low-cost solar-powered streetlight with strong reliability and durability so it can be deployed in remote and rural areas where the electric grid is not available. SERIS' approach was to develop an integrated solar streetlight where the solar panel, battery, lights, and power electronics were housed in a single enclosure. The innovation was eventually documented and filed as a patent.

Given the huge potential of its usage in developing countries, in 2013 SERIS decided not just to license the technology, but to create a spin-off company—Fosera Lighting Pte Ltd—to commercialize the technology out of Singapore. The invention with its innovation and new design approach drew strong interest from investors, and the first products under the COMMLIGHT brand were launched in 2014.[24] Since then, COMMLIGHT has grown its market to cover more than 35 countries.

The COMMLIGHT case study has aptly demonstrated that, in the journey from research and invention to the eventual commercialization of intangible assets, a critical success factor for any innovation-led enterprise is to have a novel patented technology with proven commercial merits to potential investors. Fundamentally, the product must address a market need so that there is a ready demand for the product when the solution is offered.

Completing the innovation value chain with IP

A world-class legal framework and robust IP regime are fundamental enablers that are necessary to creating a Living Lab. Singapore

BOX 1

Methodology

Leveraging its in-house patent search and examination expertise, IPOS-International (IPOS-I) developed the patent analytics capability to serve the needs of the Singapore government. Since then, IPOS-I has partnered with several public agencies to help solve organizational challenges, identify worldwide trends, and spot areas of opportunity as well as support Singapore's R&D capability through patent landscape analytics. This box broadly describes the methodology used in this chapter.

Dataset and search

The dataset comprises worldwide patent applications relating to photovoltaic (PV) technologies encompassing upstream silicon ingot and wafer manufacturing; mid-stream PV cell-, module-, and system-level inventions; and downstream PV-hybrid plants and PV-grid integrations published from 2008 to 2017. The dataset was retrieved on 11 December 2017 from the Derwent World Patents Index™ (DWPI), which is one of the most comprehensive databases containing patent applications and grants from 44 of the world's patent issuing authorities. A 'DWPI patent family' is a group of patent applications and patents related to the same invention. The search strings used incorporated combinations of keywords (and their variants) and/or patent classification codes and indexing—for example, International Patent Classification (IPC) and Cooperative Patent Classification (CPC).

The main keywords used are:

- Solar, photovoltaics; cell, film, panel, module, array, concentrator, system, farm, plant
- Floating platform, structure, lake, waterbody, water surface, reservoir, offshore, pond, pool
- Predict, forecast, outlook, future, trend, anticipate, estimate; sunlight, solar irradiance, solar radiation, weather, cloud, atmosphere
- Optimize, distribute, regulate, manage, control
- Main IPC/CPC codes used are:

H01L-031/04, H01L-031/05, H01L-031/06, H01L-031/07, H02S, Y02B-010/1, Y02E-010/5, Y02E-010/6.

Counting inventions by number of unique DWPI patent families

The patent landscape analysis report counts the number of inventions by the number of unique DWPI patent families. Counting individual patent applications will inevitably result in double counting because each patent family may contain dozens of patent publications if the applicant files the same invention for patent protection in multiple destinations. Therefore, analyses based on counting one invention per DWPI patent family can reflect innovation productivity more accurately.

Categorization of technology sub-domains

Categorization of individual DWPI patent families into respective technology sub-domains was carried out based on patent classifications codes.

Manual review

At each stage—that is, search, data cleaning, and categorizing technology sub-domains—a manual review was carried out to ensure the relevance and the accuracy of the data.

has traditionally done well in these areas.[25] However, IP can go much further in driving innovation. The research, development, and test-bedding of technology comprise but the first half of the innovation value chain. To create a positive impact on society, technologies must be brought to market.

Leveraging Singapore's conducive business environment and extensive global networks, IPOS has evolved from its traditional role as a registry and regulator to become a builder of Singapore's innovation ecosystem. It does so by working with other public agencies and enterprises to use IP as an enabler to transform ideas to assets to the market.

At the policy level, IPOS is working closely with public agencies such as the National Research Foundation, A*STAR, and many others that are involved in managing research projects or driving innovation in their respective fields to develop the National IP Protocol. The new IP Protocol lays down key principles and guidelines on how agencies should manage government IP. The protocol makes it clear that agencies should focus on IP commercialization by allowing the industry access to publicly funded R&D to create and capture greater economic value for Singapore.

IPOS is also deeply involved in helping realize the value of Singapore's IP assets. Through the

IPOS subsidiary IP ValueLab (IPVL), the agency is lending its deep technical IP knowledge to the rest of the government agencies in the areas of identifying, developing, and managing their portfolio of intangible assets that result from their innovation activities. A team of IP management consultants are tasked to advise and work with various government agencies to identify, evaluate, manage, and eventually create value from their intangible assets.

Since the beginning of the year, IPVL has also intensified its engagements with Singapore-based enterprises to assist them in identifying and growing their intangible assets so that they can scale up and grow internationally. In Singapore's recent update to its IP Hub Master Plan, where IP commercialization was identified as one of its key strategic thrusts, IPOS has committed to provide customized one-on-one IP audit and IP strategy assistance to 150 companies.[26]

To equip local businesses with IP know-how and management expertise, IPOS has partnered with the Singapore Business Federation, Singapore's largest business association, to help some 25,000 of its members access its suite of IP services. These include IP training and education as well as advisory services in IP management and strategy.

This suite of IP services complements Singapore's value proposition as a Living Lab, completing the innovation value chain to bring tangible socioeconomic benefits to the society. As it transforms into an innovation agency, IPOS will continue to innovate and update its service offerings to support local and global innovators.

Conclusion

Using Singapore and PV technologies as an example, this chapter has shown how small countries can play an outsized role in driving innovation.

The Living Lab concept can create a significant value to small countries in enabling experimentation, innovation, and collaboration among global innovators, allowing them to rapidly develop, test, and deploy new technologies in their innovation ecosystems. In feeling the pulse of the global innovation landscape, policy makers and enterprises can look at patent analytics and landscaping as a useful decision-making instrument to gain a keen understanding of business or economic sectors where they intend to direct their R&D efforts and investments.

It is clear that the national IP office plays a critical role in developing a vibrant innovation ecosystem by creating a robust legal framework and IP regime. Beyond this, the IP office can complete the innovation value chain by working with other public agencies in the ecosystem, lending its deep IP expertise to enterprises to enable them to bring their technologies to market, and transforming ideas to strategic assets.

Notes

1 Ministry of Environment and Water Resources, Singapore, 2016.

2 IEA, 2017b.

3 IEA, 2016b, p. 407.

4 IEA, 2017a.

5 Bloomberg New Energy Finance, 2017.

6 Bloomberg New Energy Finance, 2017.

7 Frankfurt School, 2016, p. 20.

8 IRENA, 2017.

9 Energy Research Institute, 2015, p. 11.

10 Reuters, 2017.

11 Bajpai, 2017.

12 IEA, 2015, pp. 21, 87.

13 Prayas (Energy Group), 2015, p. 2.

14 Nanyang Technological University, Singapore, 2016.

15 EMA, Singapore, 2017a.

16 PUB, Singapore, 2017.

17 National Research Foundation, Singapore, 2016.

18 Singapore Institute of Technology, 2017.

19 REC Group, Singapore, 2016.

20 Fraunhofer ISE, 2017.

21 Ministry of Trade and Industry, Singapore, 2017.

22 Information about the Economic Development Board, Singapore, is available at https://www.edb.gov.sg/en/our-industries/urban-solutions-and-sustainability.html.

23 EMA, Singapore, 2017b.

24 Information about COMMLIGHT is available at www.commlight.net.

25 For example, see the Intellectual property protection ranking in the World Economic Forum's Global Competitiveness Index 2017–2018, available at http://reports.weforum.org/global-competitiveness-index-2017-2018/competitiveness-rankings/#series=EOSQ052.

26 IPOS, 2017.

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