CASE for Southeast Asia

Supported by:
Federal Ministry for Economic Affairs and Climate Action
IKI International Climate Initiative
on the basis of a decision by the German Bundestag

Unlocking rooftop solar PV investments in Thailand:

Facilitating policy and financial de-risking instruments

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
Agora Energiewende
NewClimate Institute
TDRI Thailand Development Research Institute
Energy Research Institute

Published by

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

In the context of CASE

The project "Clean, Affordable and Secure Energy for Southeast Asia" (CASE) is jointly implemented by GIZ and international and local expert organisations in the areas of sustainable energy transformation and climate change: Agora Energiewende and NewClimate Institute (regional level), the Institute for Essential Services Reform (IESR) in Indonesia, the Institute for Climate and Sustainable Cities (ICSC) in the Philippines, and the Energy Research Institute (ERI) and Thailand Development Research Institute (TDRI) in Thailand.

Authors:

Energy Research Institute (ERI), Agora Energiewende, NewClimate Institute

Prepared by

This report was developed by the writing team led by Siripha Junlakarn (ERI), with contributions from Phimsupha Kokchang (ERI), Peetiphat Teerakiat (ERI), Aksornchan Chaianong (ERI and Chair for Sustainability Transition Policy, Friedrich-Alexander-Universität Erlangen-Nürnberg), Supawan Saelim (Agora Energiewende) and Katharina Lütkehermöller (NewClimate Institute).

Author Contacts:

Siripha Junlakarn
(Energy Research Institute)
siripha.j@chula.ac.th

Acknowledgements

The project, Unlocking rooftop solar PV investments in Thailand: Facilitating policy and financial de-risking instruments, was developed by CASE Thailand. Data and input were collected from interviews, structured surveys, and focus groups with national stakeholders. The project team would like to thank the high-interest participation from the Energy Policy and Planning Office (EPPO), Department of Alternative Energy Development and Efficiency (DEDE), Energy Regulatory Commission (ERC), Metropolitan Electricity Authority (MEA), Bank of Thailand (BOT), Thailand Board of Investment (BOI), Eight Solar, Greenergy, and others.

The authors would like to thank all colleagues and experts who contributed insights, editorial comments, and written reviews, particularly Hanna Fekete (NewClimate Institute), Jamie Wong (NewClimate Institute), Mathis Rogner (Agora Energiewende), Nuttawat Suwattanapongtada (GIZ), Sirinut Raya (GIZ), Pin Yungyuentrakoon (GIZ), Areeporn Asawinpongphan (TDRI), and Valentina Bellesi (OECD).

On behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) within the framework of its International Climate Initiative (IKI).

CASE online:

https://caseforsea.org/
https://www.facebook.com/CASEforSEA
https://twitter.com/CASEforSEA
https://www.linkedin.com/company/caseforsea

Executive summary

Thailand has huge rooftop solar potential that could offer both benefits of diversifying the country's renewable energy sources and enabling distributed generation at the consumer level through behind-the-metre installations. Despite a surge of rooftop solar PV installations in 2023, driven by high electricity prices, the current adoption rate of rooftop solar PV systems in Thailand is still much lower than its vast potential. This gap is due to several policy, regulatory and financial risk barriers. This study systematically identifies the risks associated with rooftop solar PV investment in Thailand and quantifies these risks' impacts on financial costs (i.e., the cost of equity and the cost of debt). In addition, the study highlights suggested policy and financial de-risking instruments that can support rooftop solar PV deployment in Thailand. Key findings and recommendations from the study are as follows:

1. Policy and financial instruments for addressing administrative and permitting, power market, developer, and financial risks should be prioritised to reduce the financial costs of rooftop PV investments

Administrative and permitting, power market, developer, and financial risks altogether account for about 57% of total risk premiums that contribute to higher financial costs for rooftop PV investments. De-risking instruments mitigating these four risk categories could lower the cost of equity of rooftop solar PV investments by as much as 2.4% points and the cost of debt by as much as 1.7% points. These risks mainly arise from complex and time-consuming permitting process for rooftop solar installations, unattractive incentives and policies supporting rooftop solar programmes, a lack of experience and limited track records of success for small developers, and restricted access to finance caused by poor loan conditions.

2. Developing a one-stop shop or centralised platform that simplifies permitting, streamlines equipment registration, and offers an online application process, could significantly boost rooftop solar PV deployment by reducing administrative and permitting costs, improving forecasting accuracy, and easing processes for all stakeholders.

Addressing the sources of administrative and permitting risks could lower the cost of equity by about 1% point. The initiative to develop a platform for streamlining and expediting permits across the electricity industry is therefore an important step that could lower costs and time for rooftop solar installations while also reducing the number of unregistered rooftop solar PV systems. This platform could evolve into a 'one-stop shop' or centralised platform for permits that offers a simplified process for online applications, alongside a consolidated information repository of qualified equipment standards, available financial products, real-time updates of new policy incentives and regulations, and a system to track and monitor applications. Collaboration between government and utilities will be vital for implementing such a centralised platform.

Moreover, data from the centralised platform on PV installations could help refine long-term rooftop solar PV targets. It would improve system operations, especially at the distribution level, by improving demand forecasts, and unlocking a new level of grid management capabilities. Such information would also benefit the evaluation of the grid's 'hosting capacity', that is, the capacity of the grid at a specific location to accommodate additional solar power. This would help ensure the grid integration of rooftop solar systems and attract consumer participation by reducing administrative costs and the need for individual interconnection studies.

3. Aligning long-term rooftop solar PV targets and support programmes with grid planning can mitigate power market risks and unlock flexible system services through demand response from distributed energy resources including energy storage systems.

Power market risks, particularly those caused by inconsistent (stop-and-go) policy support and inadequate incentives significantly hinder investment in rooftop solar PV. In addition, there is no current programme supporting rooftop solar installations by commercial and industrial consumers. These barriers increase the cost of equity and debt by as much as 0.7 and 0.8 % points, respectively. Setting long-term targets for rooftop solar PV deployment in conjunction with steady supporting programmes for all residential, commercial, and industrial consumers would establish a consumer market and improve investor confidence. If the support programmes are well-aligned with grid planning and operations, new rooftop solar systems paired with energy storage systems can significantly enhance grid flexibility by enabling demand response capabilities and reducing peak demand cost-effectively through well-designed incentive programmes.

4. To reduce developer risks, Thailand should prioritise policies that enhance developer transparency, mitigate financial risks in third-party ownership contracts, and establish a clear pathway for solar waste management and second-life markets.

Developer risks pose significant challenges for both investors and financial institutions. Such risks can be caused by a lack of experienced and certified solar installers, uncertainties in third-party ownership contracts, both of which can lead to unforeseen costs. Effectively addressing these risks can reduce the cost of equity and the cost of debt by up to 0.6 and 0.5% points, respectively. Potential actions include promoting customer review platforms for solar companies, establishing partnerships with financial institutions for credit checks on potential companies, and implementing strategies to mitigate customer non-payment risks. A clear timeline and regulation for solar waste management, including the viability and market potential for used solar panels, would enable clear business plans for the end-of-life phase of PV systems and reduce business uncertainties.

5. Financial de-risking instruments can play crucial roles to reduce costs arising from limited access to finance, unattractive loan conditions, and lender risk aversion.

Financial risk, one of the top three most significant risks associated with rooftop solar PV investment in Thailand, is likely to stem from unattractive loan terms, lender's singular focus on repayment, and volatile exchange rates. If this risk is mitigated, the cost of debt could decrease by as much as 0.5% points. Several financial de-risking instruments could be developed through collaboration between financial institutions and government agencies, including risk-sharing mechanisms such as loan guarantees, partial risk guarantees and performance-based incentives. In addition, specific loan programmes could be tailored for rooftop solar PV projects, which offer more favourable interest rates and longer loan terms that reflect the specific cash flow patterns of solar energy generation. Furthermore, through collaboration with insurance companies, new specific insurance solutions could be offered to cover losses or damages to solar panels and associated equipment, thereby reducing the risks arising from interruptions in energy production.

CASE
for Southeast Asia

Table of Contents

1 Introduction

As a global crisis that transcends national borders, climate change stands as a paramount challenge demanding collective and coordinated efforts across all levels and nations. Thailand, like many other countries, grapples with the urgency of this issue and has made a significant commitment to address it, pledging to achieve carbon neutrality by 2050 and reach net-zero greenhouse gas emissions by 2065.

Thailand must increase its share of renewable energy (RE) to meet its climate targets.

To meet these targets, Thailand faces a pressing need to substantially increase its share of RE. The necessity to transition away from conventional fossil fuels is underlined not only for carbon emissions reduction but also to mitigate economic risks associated with potential carbon mechanisms and volatile fossil fuel prices. Thailand's imperative to increase the share of RE is evidenced in the draft National Energy Plan, which aims for RE to account for at least 50% of total new generating capacity by 2037. Furthermore, Thailand has submitted its Long-Term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) (ONEP, 2022) to the United Nations Framework Convention on Climate Change (UNFCCC) with the projection of renewable electricity shares to be 68% by 2040 and 74% by 2050.

Despite its high solar potential, Thailand has witnessed limited investments in utility-scale solar projects in recent years due to unclear policy directions.

Thailand holds immense solar potential due to high solar irradiance. Greater utilisation of this domestic resource could reduce demand for energy imports and improve Thailand’s energy independence. Thailand’s solar technical potential could be over 300 GW when considering only high irradiance (>1,850 kWh/m^2) which only takes up to less than 2% of the total land area (CASE, 2022). Despite the high solar potential and the lower costs of solar technology (IRENA, 2023), Thailand has witnessed limited investments in utility-scale solar projects in recent years.

These limited investments can be attributed to various factors. Firstly, the lack of a clear and finalised national energy plan (NEP) and power development plan (PDP) creates uncertainty for investors. While the long-term strategy (LT-LEDS)[1] exists, details on implementation and specific measures for the energy sector are still under development in the NEP and PDP. Secondly, the current electricity market structure, an enhanced single buyer (ESB) model, presents challenges for private investment in large-scale solar projects. While a feed-in-tariff (FiT) programme incentivises RE projects, the schedules for electricity procurements are strictly set by policy through the PDP, introducing unpredictability and capacity constraints. This hinders the optimal and timely expansion of solar energy, making it difficult to achieve long-term RE goals by 2037 and 2050. Thirdly, the existing ESB model with long-term power purchase agreements (PPAs) disincentivises new, efficient utility-scale RE projects including solar. The focus remains on existing power plants, which may even exceed current demand. Finally, the perception of solar PV technology as a variable source raises concerns among utility authorities. They worry about its impact on grid reliability, potentially requiring significant investments in energy storage systems (ESS) or additional dependable fossil fuel generation.

1 The draft PDP2024 was recently released in June 2024, with the goal of increasing the generation capacity to 112 GW by 2037, with 50% of this capacity coming from renewable sources, including 17% from solar PV.

As the implementation of large-scale solar integration is meticulously deliberated, the potential for rooftop solar PV for end-users is expanding.

There is a growing interest in rooftop solar PV installation among electricity consumers in Thailand. The cost of solar PV has significantly decreased over the years and the generation cost from solar PV reaches the grid parity[2], making it a cost-effective option for end-users. The continuous enhancement of technology, increasing its efficiency, has further spurred the widespread use of rooftop solar PV. In addition, in recent years, loans for rooftop solar PV installations have become more widely available, particularly in the commercial and industrial sectors. Notably, third-party ownership business models and private PPAs between solar system owners and electricity consumers are becoming increasingly prevalent. Taking these factors into consideration, end-users might be motivated by factors such as cost savings, environmental awareness, and external pressures related to climate issues (e.g. Carbon Border Adjustment Mechanism), fostering a keen interest in rooftop solar PV installations.

Despite the high potential of rooftop solar PV in Thailand, its adoption rate is slow and there is considerable room for improvement in strategies to promote it.

Rooftop solar PV investments have the potential to support Thailand's climate target. In 2037, the technical and market potentials for rooftop solar PV energy in Thailand are projected to be approximately 226,000 MW and 9,000 MW, respectively (Tongsopit, Junlakarn, Chaianong, Overland, & Vakulchuk, 2024)[3]. In 2022, the cumulative number of rooftop solar PV installations was approximately 1,800 MW. Although the levelised cost of electricity (LCOE) for rooftop solar PV across all customer groups has reached grid parity since 2019 (Tongsopit, et al., 2019), adoptions of solar PV continue to be contingent on a number of variables, including the high upfront cost, limited rooftop space, non-consumption of electricity during the day, ease of maintenance, and so forth. However, several uncertain factors can be mitigated through well-designed policy and financial instruments.

The financial and policy de-risking instruments remain poorly understood by key stakeholders, especially policymakers.

Although installing a rooftop PV system can provide system owners with numerous benefits, it is important to note that there are still associated risks. Identifying these risks and understanding the underlying barriers is crucial to mitigating financial costs. Interventions through several policies and financial de-risking instruments could play a vital role in this process. Strategically crafted incentives can create favourable business environments, accelerating the adoption of rooftop solar PV and expanding access to financing for individuals. Nevertheless, this must align with a well-designed power system development plan in order to alleviate the potential impacts of distributed solar PV.

[2] Grid parity is where the levelised cost of electricity (LCOE) of solar PV is comparable to the cost of purchasing electricity from the grid. More information about the LCOE is given in Chapter 2.

[3] The solar capacity figures represent the conservative scenario.

The primary contribution of this study is to enhance the understanding and awareness of crucial stakeholders regarding the potential of financial and policy de-risking instruments to improve the risk-return characteristics of investments in RE. By systematically identifying and quantifying the potential risks associated with rooftop solar PV projects in Thailand, a combination of existing and prospective de-risking policies and financial instruments, drawing insights from lessons learnt in other countries, can be implemented in an effort to alleviate these risks. The study findings are organised into three sections, as illustrated in Figure 1-2.

Figure 1-2 Overview of study

Part 1: Risk environment (Chapter 3)

- What are the risks for investment in rooftop solar and the underlying barriers?
- What are the impacts of these risks on financial costs?
- Which risks should be prioritised for the de-risking instrument package?

Part 2: Existing de-risking policy and financial instruments (Chapter 2 and 4)

- What are existing de-risking policy and financial instruments in Thailand and their current utilisation/ barriers for implementation?
- What are the lessons learned from existing de-risking instruments in other countries?

Part 3: Recommendations for a suitable mix of policy and financial de-risking instruments (Chapter 5)

- Which de-risking instruments could be developed in Thailand based on experience in other countries?
- Which de-risking instruments could be improved/developed in the future for Thailand?

2 Thailand's rooftop solar PV situation: Policies, investments and existing policy and financial instruments in Thailand

2.1 Current status of Rooftop solar PV and ESS

2.1.1 Rooftop solar PV status

Beginning in 2018, rooftop solar PV has grown from two main programmes: self-consumption with no excess electricity and residential with excess electricity incentives.

In Thailand, rooftop solar PV development has been encouraged through supporting policies and financial mechanisms. In the past, the growth of rooftop solar PV installations was supported by premiums and regular FiT programmes. While the current government support programme may not be as appealing as it once was, the gradual increase in behind-the-meter rooftop solar PV installations can be attributed to the ongoing cost reductions of solar PV systems. At present, rooftop solar PV installations for self-consumption are permitted for all electricity users. However, any excess electricity generated by the PV systems is prohibited from being fed into the power grid. The only available programme that allows excess electricity to be fed into the grid is the residential solar programme. In 2022, the cumulative number of rooftop solar PV installations reached over 1,800 MW[4]. This number includes governmental support programmes as well as the independent power supplies or the private sector's distributed PV systems, as shown in Table 2-1 and Figure 2-1.

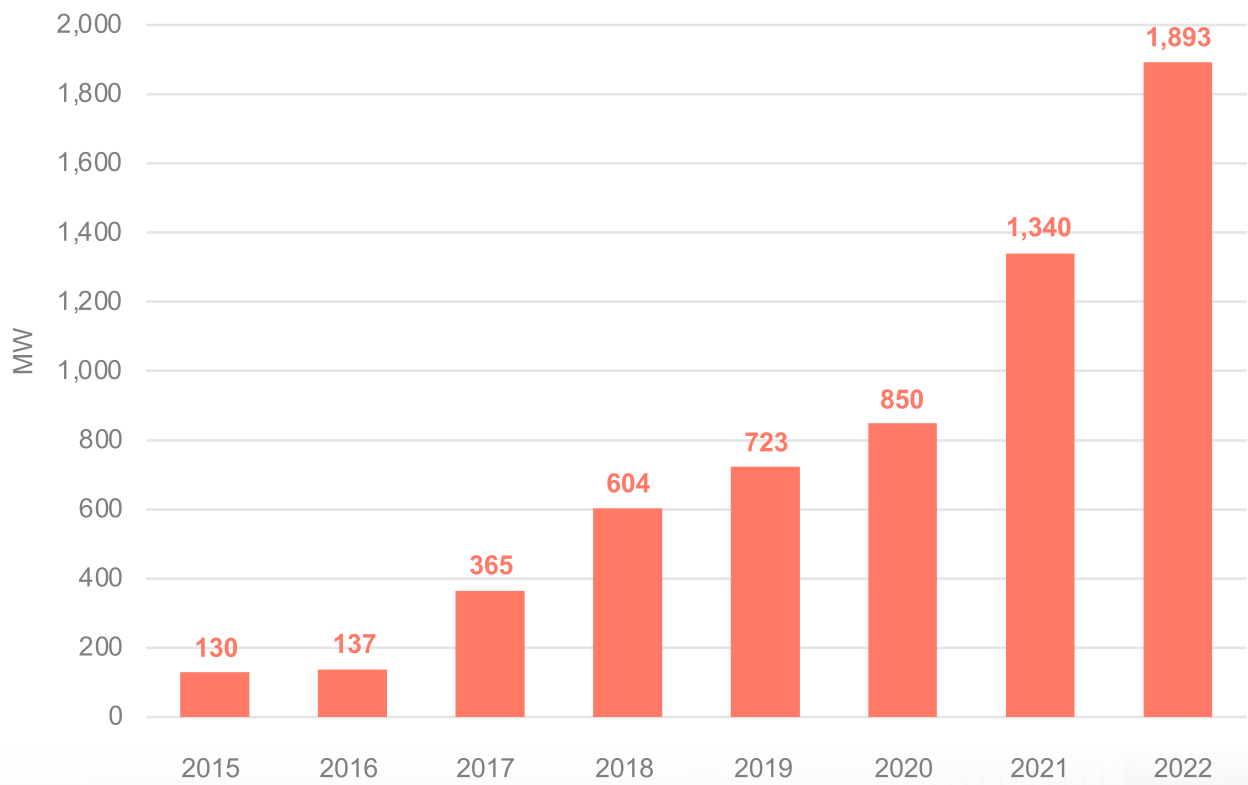
Table 2-1 Cumulative installed capacity of rooftop solar systems from 2013-2024, classified by programme types[5]

Year implemented (status)	Programme	Customer target group	Achieved (MW)
2013-2015 (completed)	FiT	Residential Commercial & Industrial	130
2017 (completed)	Self-Consumption only (Pilot Project)	Residential Commercial & Industrial	5.63
2018 (ongoing)	Self-Consumption only (No export)	Residential, Commercial & Industrial	1,673
2019-2020 (completed)	Net-billing with buyback rate of 1.68 THB/kWh	Residential (≤ 10 kW)	5.42
2021-2024 (ongoing)	Net-billing with buyback rate of 2.2 THB/kWh	Residential (≤ 10 kW)	25.43 (as 2022)

[4] The data were compiled by authors from different sources including the Thailand PV status report 2020, PV GIS KMUTT, and Solar working group 2023.

[5] The data were compiled by authors from different sources including the Thailand PV status report 2020, PV GIS KMUTT, and Solar working group 2023.

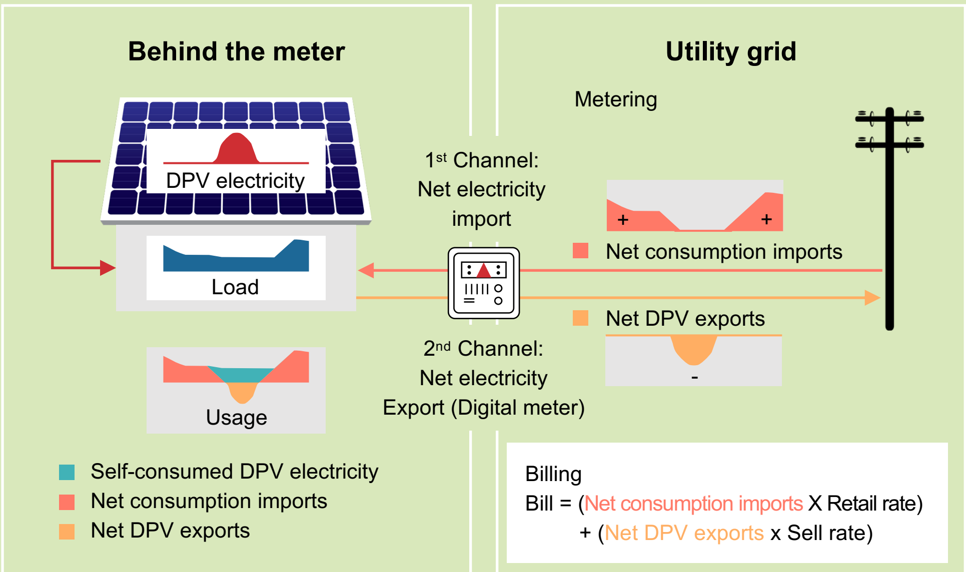
Figure 2-1 Cumulative installed capacity of rooftop PV systems from 2013-2022

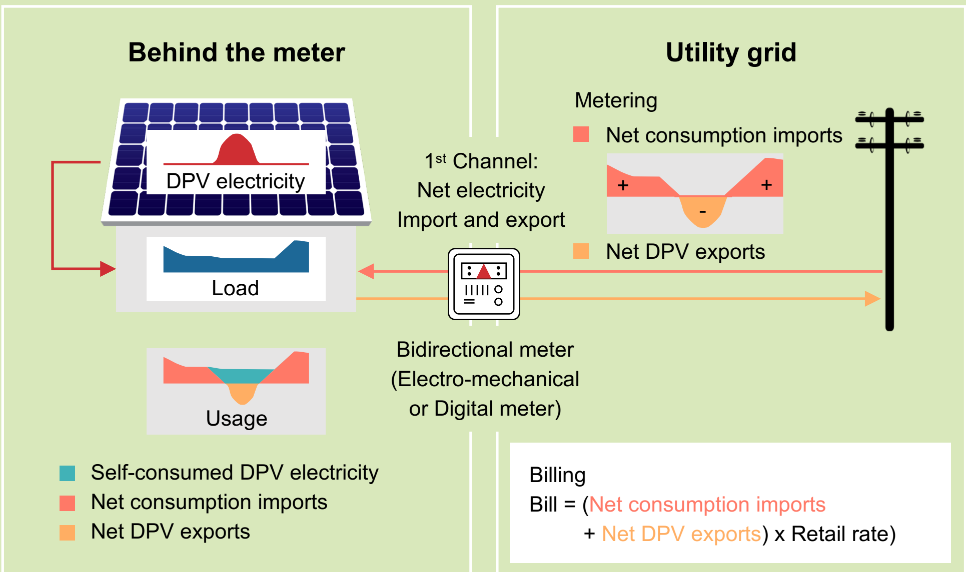


CASE for Southeast Asia

BOX-1: Net-billing vs Net-metering schemes

For **both supporting schemes**, the PV electricity is self-consumed, and prosumers purchase grid electricity at the retail rate. Regarding the **net-billing scheme**, excess PV electricity injected into the grid is compensated at different monetary rates (which are normally lower than the retail price such as in the case of Thailand). At the end of the month, customers pay the difference between costs of imported and exported electricity. In contrast, for the **net-metering scheme**, the excess PV electricity offsets the grid electricity consumption each month (the value of PV electricity equals the retail rate).





Net-billing (above) vs Net-metering (below) schemes

These two schemes are examples of support mechanisms that enable prosumers to choose their electricity generation options and manage their excess generation. To select the appropriate mechanism, it is necessary to understand their objectives and ensure fairness across all sectors.

2.1.2 ESS status

ESS are becoming crucial for integrating variable RE sources, including solar and wind power. On the demand side (behind-the-meter ESS), they help store excess energy produced by solar PV systems, particularly during times when solar output exceeds current demand. This stored energy can then be used later when needed, increasing self-consumption and reducing reliance on grid purchases during peak pricing periods. On the supply side, ESS integrated with energy management systems can regulate power generation and consumption, smoothing out fluctuations in solar energy and maintaining grid stability.

While various ESS technologies exist, only two are widely discussed in Thailand. Lithium-ion batteries are popular due to their compact size, lightweight design, high efficiency, safety, and long lifespan. They can be used in both residential and commercial applications. Sodium-ion batteries are an additional cost-effective alternative to lithium-ion batteries. They are well-suited for certain applications, such as community power initiatives, that do not necessitate exceptionally high performance.

However, high costs remain a major barrier to widespread ESS adoption. One particular study (Chaianong, Bangviwat, Menke, Breitschopf, & Eichhammer, 2020) highlights the significant impact of battery size, cost, and retail electricity pricing on residential solar-battery systems. Therefore, policy support and incentives are necessary to encourage greater adoption of this technology.

BOX-2:
Examples of current ESS-related policy support and incentives in Thailand

- FiT: The Energy Regulatory Commission (ERC) has implemented measures to promote energy production from efficient RE sources including guidelines that facilitate the installation of ESSs. ERC regulations have been established for the procurement of electricity from RE sources through the FiT programme 2022-2030 (ERC, 2022). The programme mainly focuses on groups with no fuel costs, promoting the integration of a ground-mounted solar power system combined with an ESS. The outlined objective is to procure 1,000 MW from these systems between 2024 and 2030.
- Tax incentives: The Board of Investment of Thailand (BOI) offers tax benefits and lower excise tax rates for imported energy storage to encourage investments (BOI, 2024). However, there is a specific condition that the manufacturers must incorporate investment packages for electric vehicle (EV) batteries (TDRI, 2019).
- Research and development support: Support is provided for research and development of energy storage technology used in Thailand, such as pilot projects to evaluate how effective and viable it is to implement energy storage in businesses and communities. Moreover, the cooperation between the private sector and educational institutions is promoted to support the development of ESS through initiatives like capacity building.

Additionally, the Ministry of Energy, through the Energy Policy and Planning Office in conjunction with related agencies, has formulated an action plan to promote the battery ESS industry in Thailand from 2023 to 2032 (EPPO, 2023), as follows:

- Focusing on the power system, the plan includes guidelines for adjusting power purchase contract formats, encouraging the installation of ESS in conjunction with variable RE integration, using ESS to delay investment in expanding transmission and distribution lines, enhancing grid stability from ESS (battery ancillary services), and providing various benefits for domestically produced ESS (such as direct financial support).
- Promote competitiveness in sustainable battery production by supporting government-to-government (G2G) and business-to-business (B2B) cooperation, facilitating the private sector through the establishment of a one-stop service, and promoting ESS production plants with zero carbon emissions.

In addition to the above mentioned, there are also legal, regulatory, standard, research, and development support plans to foster the complete promotion of ESS within the country.

2.2 Existing instruments supporting rooftop solar in Thailand

2.2.1 Policies

In Thailand, there are several governmental initiatives in place to foster rooftop solar PV investment-friendly business environments. These include:

Self-consumption programmes:

Since 2018, all electricity customer groups have been permitted to install rooftop solar PV systems for self-consumption with no surplus electricity fed back into the grid. However, in 2019, the residential solar programme was introduced to incentivise homeowners (installed capacity ≤ 10 kW) to install rooftop solar PV systems for self-consumption and to sell the excess electricity to the grid over a ten-year contract period. For its initial implementation in 2019, the programme used a net-billing mechanism with a buyback rate of 1.68 THB/kWh. The initiative was not effective due to the comparatively low buyback rate, which resulted in a limited number of applicants. In 2021, the buyback was increased to 2.2 THB/kWh and received a greater response.

Tax incentives[6] for solar PV installations by cooperatives:

BOI is a crucial driver in advancing the adoption of clean energy, particularly through its active promotion and support of investments in solar projects. By offering incentives like tax reductions and additional privileges, the BOI attracts both domestic and international investments, with a specific focus on alleviating the cost burden associated with solar projects. To qualify for BOI promotion, applicants for solar installations must submit investment plans focusing on energy-saving machinery, RE, or environmental impact reduction. This policy aims to alleviate project costs by waiving import duties on machinery (solar panels and inverters) and providing a three-year exemption on corporate income tax, which can cover up to 50 percent of the investment, excluding land and working capital expenses. This tax exemption commences from the date of earning income, following the receipt of the BOI promotion certificate, and lasts for three years from the certificate issuance date.

Off-grid solar programme:

Rooftop solar PV installations serve as a vital source of electricity in remote regions, particularly for facilities such as hospitals and schools with limited access to conventional grid infrastructure. To promote RE adoption, the Department of Alternative Energy Development and Efficiency (DEDE) has initiated an off-grid programme encouraging the installation of rooftop solar PV systems in remote healthcare facilities, educational institutions, and for various energy needs including drying, water pumping, and agricultural farming. This programme efficiently addresses the energy requirements of remote communities, offering government funding as financial assistance to promote rooftop solar PV installation. One notable initiative under this programme is the Koh Jik Recharge Project (Veilleux, et al., 2020), which exemplifies this effort. Additionally, the programme incorporates the Pay-As-You-Go (PAYG) model, where residents pay for electricity consumption through pre-paid meters (OECD, 2024). This not only helps cover operating costs but also generates revenue for further RE development in the community, thus enhancing energy access and sustainability.

[6] Besides cooperative, there is a drive being made for a tax exemption initiative for residential solar photovoltaic installations (Prachachat Online, 2024).

Regulatory sandbox programme:

ERC launched the sandbox programme in 2019, enabling testing of innovative energy concepts with relaxed regulations. One of the key concepts that is being tested is peer-to-peer (P2P) energy trading, enabling prosumers with rooftop solar PV to directly trade or share excess energy with neighbours. This not only has the potential to increase monetary benefits for prosumers but also promotes clean energy practices and provides customers with choices aligned with community values. Rooftop solar PV, an essential element in these innovative concepts, benefits significantly from the sandbox's flexible regulatory framework, which fosters experimentation and enables widespread adoption in Thailand. The sandbox programme was expected to provide a catalyst for improving community-centric and sustainable energy practices through initiatives such as P2P energy trading, notably contributing to the deployment of rooftop solar PV systems in Thailand. However, the results of these initiatives remain uncertain.

2.2.2 Business models, financing options and financial incentives

Since the FiT were introduced in 2013, several business models for rooftop solar PV have emerged (Tongsopit, Moungchareon, Aksornkij, & Potisat, 2016; Potisat, Kuvarakul, Yaowapruek, & Moungcharoen, 2017). These models include self-financing, leasing, third-party ownership, and roof rental (Table 2-2). Table 2-3 compares drivers, barriers, and risks of these solar business models. Currently, the two most prevalent business models in Thailand are self-financing and third-party ownership.

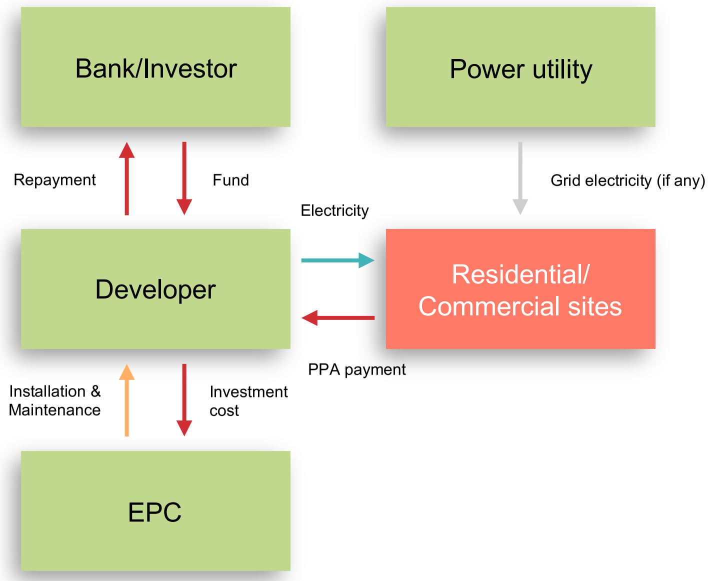
Table 2-2 Summary of existing solar business models in Thailand

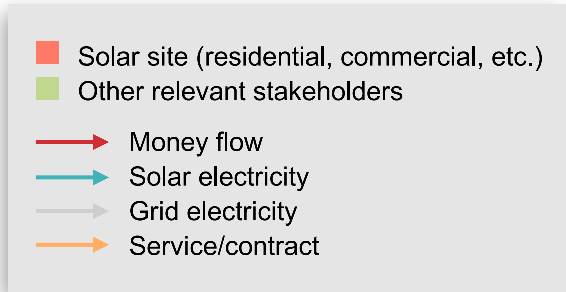
Business model and description	System ownership	Consumer benefit	Customer cost
Self-finance[7] • The consumer/owner installs the rooftop solar system through their personal funds, which may consist of equity, debt, or a combination of both. • Engineering, procurement, and construction (EPC) company or installer company designs and constructs the rooftop solar system.	Consumer/owner	Solar electricity bill savings, and/or sale of electricity to the grid in some cases	Payment for installation and maintenance

Source: Tongsopit, Moungchareon, Aksornkij, & Potisat, 2016; GIZ and USAID, 2017

[7] Thailand also refers to the self-finance model as the engineering, procurement, and construction (EPC) model.

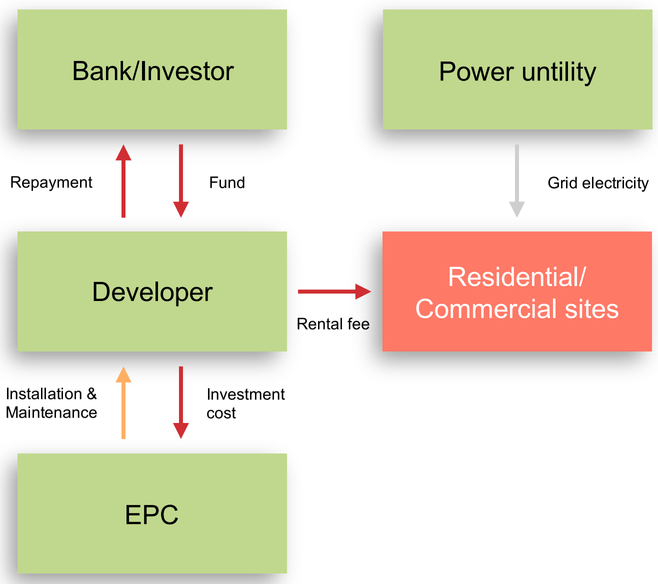
Business model and description	System ownership	Consumer benefit	Customer cost
Third-party ownership[8] • The solar service providers build, own, and operate the rooftop solar system and sell solar electricity to consumers at an agreed rate, typically lower than the grid electricity price.	Solar service provider/solar PPA company	Solar electricity/bill savings	PPA payment

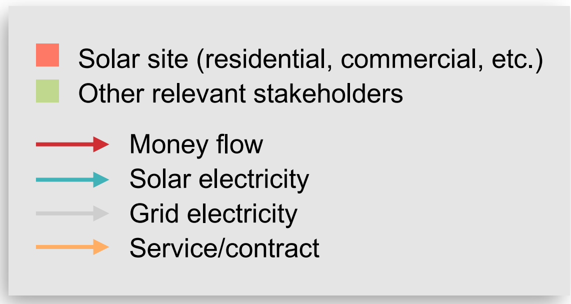




[8] Thailand also refers to the third-party ownership model as the private power purchase agreement model.

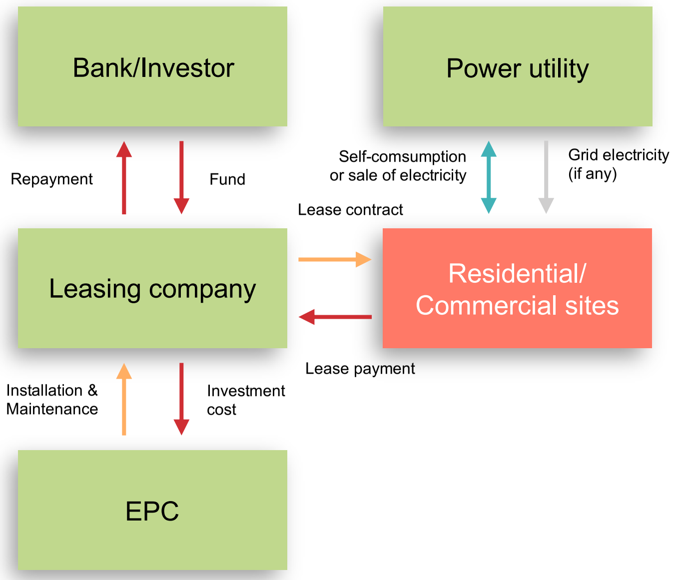
Business model and description	System ownership	Consumer benefit	Customer cost
Roof rental • The developers/ solar service providers rent consumers' roofs to build, own, and operate the rooftop solar system.	Developer/ solar service provider	Rental fee	n/a





Note: Selling electricity from PV systems depends on the developer's business (e.g. selling to power utility, or PPA with customers in the housing estate).

Business model and description	System ownership	Consumer benefit	Customer cost
Leasing • The consumers lease the solar system from the leasing company. Solar electricity can either be self-consumed or sold back to the grid.	Consumer	Solar electricity/bill savings, and/or sale of electricity to the grid in some cases	Lease payment



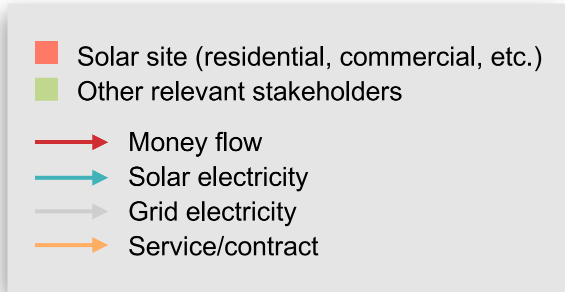


Table 2-3 Comparison of drivers, barriers, and risks of existing solar business models in Thailand

Business model	Driver	Barrier	Risk
Self-finance	• Grid parity or competitive levelised cost for solar electricity, with or without policy support • Ease of regulations	• High capital cost • Difficult loan acquisition	• Unexpected yield/ performance from a solar system
Third-party ownership	• Grid parity or competitive LCOE of solar compared to grid electricity • Rarely needs of policy support • Operation and maintenance costs covered by providers	• Legal issues. • High investment costs for small-scale rooftop solar systems.	• Roof damage at the site • Change of load patterns that can affect the solar PPA electricity needed • Lower grid electricity so that the solar PPA electricity is not attractive.
Roof rental	• Co-benefits from rental fee and reduced heat absorption • Opportunity for housing developers adopting this model for selling their houses • Grid parity or competitive levelised cost for solar electricity, with or without policy support	• It emerged during FiT period. As a result, this model might need a presence of FiT or any attractive incentives.	• Roof damage at the site • Changing of building conditions
Leasing	• Interest from the leasing company and the consumers who cannot afford the high installed costs • Ease of regulations	• Lack of a dedicated unit to facilitate solar-related equipment markets.	• No payment from the lessee • Unexpected yield/ performance from the solar system

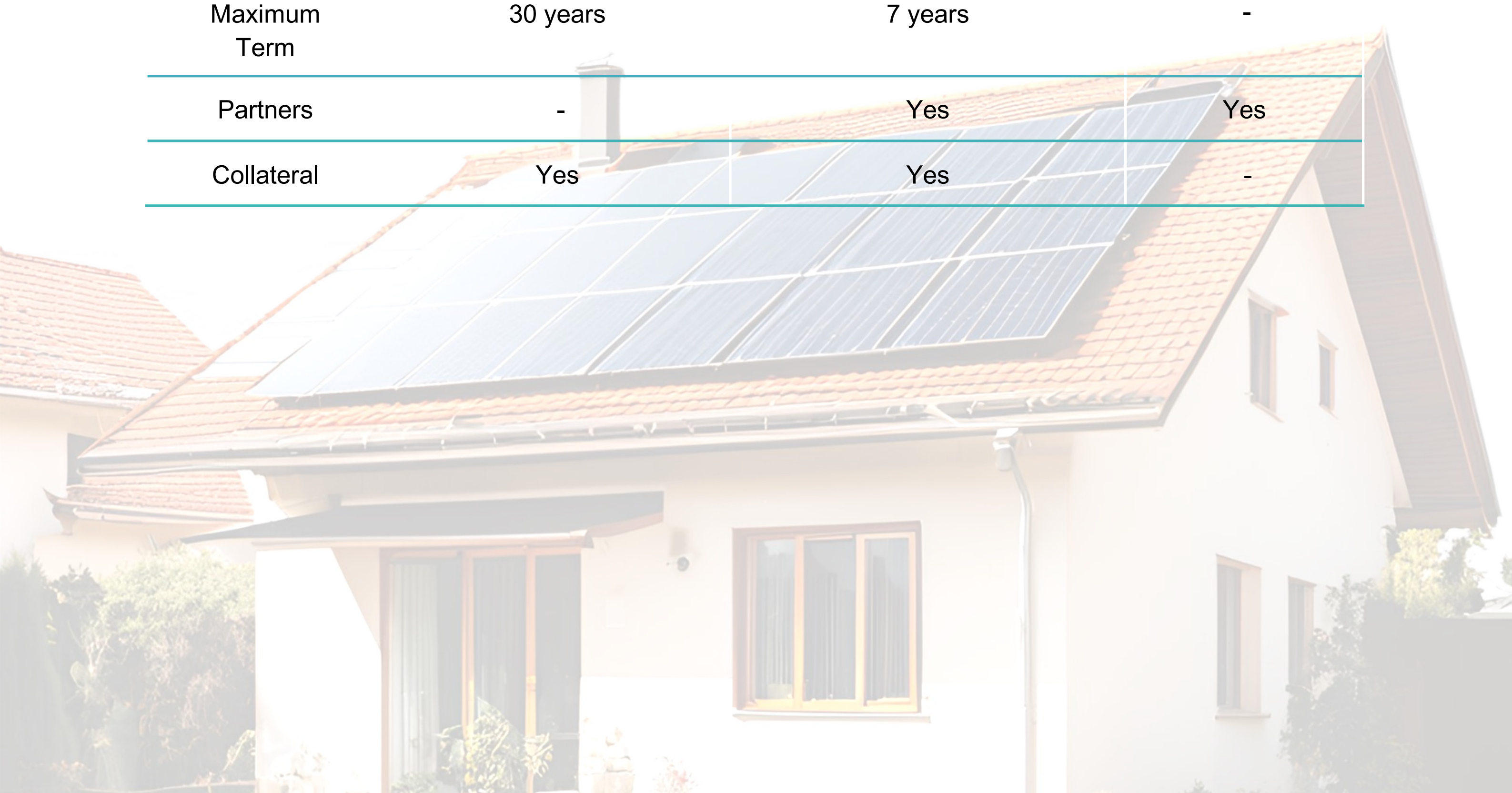
Source: Tongsopit, Moungchareon, Aksornkij & Potisat, 2016; GIZ and USAID, 2017

For self-financing alternatives, private banks in Thailand have increasingly extended loan programmes for rooftop solar PV installations to households, SMEs, and enterprises. There are a variety of options including conventional home loans, loans for the adoption of clean technologies, and solar-specific loans. Six to eight years is the longest term for the majority of solar loans for businesses. In addition, most solar finance programmes have partnerships with solar installers. Examples of solar loans are shown in Table 2-4.

Table 2-4 Loans offered for rooftop solar in Thailand

(1) Example of loans for households

	Home loan re-finance and solar loan (Kasikorn Bank, 2023a)	**GO Green – rooftop solar, EV cars, Energy efficiency appliances (GSB, 2023)**	**Solar (UOB, 2023) *For households and businesses**
Range of interest rate	3.9%	A fixed interest rate of 7.99% and monthly payments of 799 THB for 3 months	0% for 10 months or 24 months
Maximum credit line	100% (only for houses in the projects of real estate development companies that are partnering with the bank)	up to 10 times the total income, with a cap of 500,000 THB per individual	-
Maximum Term	30 years	7 years	-
Partners	-	Yes	Yes
Collateral	Yes	Yes	-



(2) Example of loans for SMEs/Businesses

	Rooftop solar Loan for Entrepreneur (Krungsri Bank, 2023) *For businesses	Go Green/rooftop solar solution (Kasikorn Bank, 2023b; TTB, 2023) *For businesses	Green lending for rooftop solar, EV charger etc. (Krungthai Bank, 2023) *For SMEs and businesses	Green forward/green loan (Bangkok Bank, 2023; SCB, 2023) *For SMEs
Range of interest rate	• Approval of interest rates is in accordance with the Bank's credit approval criteria and conditions.	• MLR - 1.00% per year (payment period not exceeding 5 years) • MLR - 0.80% per year (payment period not exceeding 8 years) • In some cases, approval of interest rates is in accordance with the Bank's credit approval criteria and conditions.	• MRR - 0.5% (Small business) - MLR - 0.5% (Medium and large businesses)	• MLR - 1.0% • Or start at MRR - 0.5%, maximum at MRR + 2.5% per year.
Maximum credit line	100% of investment cost	100% of investment cost	3 million THB (SME) 5 million THB for Medium-large businesses (no collateral)	50 million THB
Maximum terms	6 years	8-30 years	7 years	7-8 years
Partners	Yes	Yes	Yes	-
Collateral	Yes (Home to cash: maximum credit limit is 10-million-THB, instalment up to 30 years)	Yes (Machinery, mortgage, or business collateral to cover the credit limit)	No	Yes (Single house/twin house/townhouse/ condominium/ commercial building/ vacant land/ land with building (e.g. warehouse, factory), deposits, business property, machinery, personal guarantee, etc.)

Note: MRR: Minimum Retail Rate; MLR: Minimum Loan Rate

Moreover, Thai enterprises utilise green bonds, including ESG bonds aimed at financing RE and similar eco-friendly initiatives, called ESG bonds. They consist of green bonds, social bonds, and sustainability (green and social) bonds. According to the Thai Bond Market Association (ThaiBMA), as of 2021, registered green bonds in Thailand amount to approximately 53.6 billion THB, while social bonds total around 9.8 billion THB and sustainability bonds amount to 160 billion THB (ThaiBMA, 2018). These bonds are issued by commercial banks and various private entities such as Bangchak, B. Grimm, and Energy Absolute.

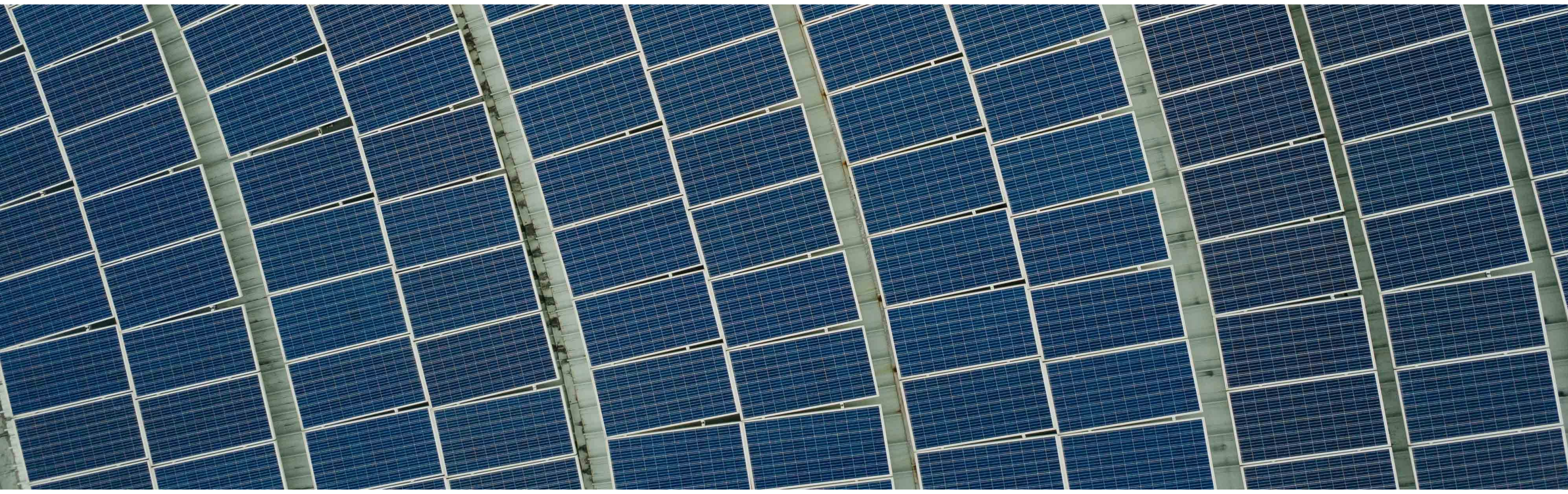
While financing options play a crucial role in making rooftop solar PV more accessible, Thailand has also implemented financial incentives to further encourage its deployment. These incentives come in the form of carbon markets and Renewable Energy Certificates (RECs), each offering distinct benefits for businesses and individuals considering solar power.

Carbon markets:

Thailand's voluntary carbon market, known as the Thailand Voluntary Emission Reduction (T-VER) programme, offers a unique financial incentive for businesses to reduce CO_2 emissions by employing clean energy, such as solar PV installations (TGO, 2016). Businesses that reduce emissions by installing solar panels earn tradable carbon credits. This creates a marketplace where these credits can be bought and sold, financially rewarding companies for their environmental efforts. The significant growth in carbon credit trading volume underscores the increasing focus on greenhouse gas mitigation, with solar energy playing a key role in achieving these goals.

RECs:

RECs offer another financial incentive for large-scaled rooftop solar PV deployment. An REC represents the environmental benefits associated with one megawatt-hour of RE generation. By generating electricity from their solar panels, system owners can earn RECs, essentially capturing the environmental value of their clean energy production. These RECs can then be sold in a dedicated market, creating an additional revenue stream that helps offset the initial investment and operating costs of the solar PV system (The Nation, 2024). This financial benefit not only incentivises businesses to invest in solar power but also fosters a broader market for RE attributes, further promoting solar adoption. Thailand's embrace of the international REC standard highlights its commitment to facilitating REC trading and supporting the growth of the solar energy sector (EGAT, 2022).



2.3 Future business models to support rooftop solar deployment

Beyond existing policy and financial instruments, several significant trends are poised to accelerate rooftop solar PV deployment:

P2P energy trading:

Inspired by the sharing economy concept, P2P energy trading is gaining traction globally, including in Thailand. This innovative model allows consumers and prosumers to negotiate and trade electricity among themselves using a P2P or business-to-business (B2B) energy trading platform (Gunarathna, Yang, Jayasuriya, & Wang, 2022). Trading prices are typically set between the export or government purchase price and the retail price, promoting community-driven energy sharing and offering financial incentives compared to traditional methods. However, significant challenges persist due to a lack of support from existing regulatory structures, technical constraints, and insufficient societal awareness or acceptance (Junlakarn, Kokchang, & Audomvongseree, 2022). To address these challenges, countries like Thailand have launched regulatory sandbox programmes to test these P2P concepts, aiming to examine and analyse regulations for future implementation.

Direct PPAs:

Direct (or sleeved/off-site) PPAs, are a significant response to global pressure for industries to shift towards clean energy sources. These agreements involve an RE generator and an off-taker, typically a business or large energy user, to directly procure electricity from RE sources such as solar or wind farms to achieve RE goals. In this arrangement, a public utility serves as an intermediary, transmitting electricity from the RE generator to the off-taker's point of intake and incurring network charges such as a wheeling charge for grid access. Additionally, depending on agreements, if the purchased RE falls short of meeting the off-taker's energy demands, the utility is responsible for providing any additional power required (Novergy Energy Solutions, 2024). RE generators have the flexibility to choose optimal locations for generation or utilise existing plants and can enter multiple PPAs with different customers, offering long-term price stability through fixed-price agreements (Next Kraftwerke, 2024). Notably, implementing this type of PPA may require Third-Party Access (TPA) regulation to ensure fair and transparent grid access for all parties involved.

Vehicle-to-grid (V2G):

V2G technology unlocks the potential of electric vehicles (EVs) as energy storage devices. V2G enables bi-directional charging, allowing EVs to not only be charged by the grid but also to feed excess power back into the system (Fields & McDevitt, 2024). By utilising this capability, EVs can store surplus electricity generated by solar PVs and other RE sources and discharge it back to the grid or for home use as needed. EV owners can optimise their usage by participating in demand response programmes or selling surplus stored energy to the grid, creating new revenue streams, and reducing the overall cost of vehicle ownership (Irfan, Deilami, Huang, & Veettil, 2023). This dual benefit serves as a powerful incentive for both EV adoption and rooftop solar PV installation, providing financial incentives to consumers while reinforcing grid resilience and optimising behind-the-meter solar generation.

3 Risk environment analysis: Underlying risk barriers and impacts on financial costs and LCOE

This chapter provides the analysis of risks and their underlying barriers for rooftop solar PV projects as well as related existing policy and financial de-risking instruments in Thailand in Section 3.1 and 3.2. The impacts of risks on financial costs and LCOE for rooftop solar PV investment are analysed in Section 3.3.

The method for analysing the risk environment and impacts on financial costs and LCOE includes both qualitative and quantitative analysis, including desk review, semi-structured interviews, and focus groups conducted during December 2022 to June 2023. The stakeholders participating in the interviews and focus groups were representatives from the private sector, government organisations, and financial institutions (see Annex 1 for more details of methodology).

3.1 Risks and underlying barriers for Thai rooftop solar PV investment

Based on input from the desk review, semi-structured interviews, and focus groups, the key risks and underlying barriers for rooftop solar PV investment in Thailand were identified into eight risk categories as described in Table 3-1.

Table 3-1 Summary of key risks related to rooftop solar investment in Thailand

Risk	Underlying barriers
1. Power market risk	• **Unattractive incentives and policies to support rooftop solar PV installations.** The past and current rooftop solar PV schemes designed for households with low buyback rates appear to have failed to generate significant interest, leading to low adoption rates compared to the scheme target capacity. With low buyback rates, the investment in rooftop solar PV installations provides a lengthy payback period for households that typically have low electricity consumption during the day. In addition, despite the self-consumption scheme with no excess electricity export being offered for all system scales, a number of industrial and commercial customers with the capacity to install larger systems are compelled to install smaller systems in order to mitigate the export restriction on weekend electricity surpluses. • **Uncertainty and lack of continuity regarding policies to support rooftop solar investments.** This is due to the government is unsure about the technical and economic impacts that may arise from increased installation of rooftop solar PV systems. • **Lack of planning and cooperation among government agencies.** For instance, due to the fact that rooftop PV systems are installed behind meters, actual electricity demand cannot be determined in the absence of cooperation and planning among power utilities; consequently, electricity demand forecasting may be overestimated or underestimated. This concern gives rise to intricate regulations and policies pertaining to installation. • **Insufficient support for innovation, technology, or new business models for rooftop solar.** Despite the fact that government agencies have investigated the viability of new business models for solar PV (e.g. prosumer market, P2P energy trading), there are no definitive conclusions or guidelines to support regulations regarding the initiatives' broader ramifications. The future course of action is contingent upon the structure of the electricity market in Thailand.

Risk	Underlying barriers
2. Administrative & permitting risk	• **Complex and time-consuming permitting process.** This results in exorbitant expenses and a lack of transparency due to the requirement to obtain permits from several government agencies (including non-energy agencies). Investors must also adhere to laws and regulations before getting a permit. For instance, for solar rooftop installations exceeding 1 MW, a permit for factory operation is required. However, this regulation is expected to be lifted soon. • **Complicated standard certification or equipment registration.** Distribution power utilities promote product registration among suppliers of electrical equipment utilised in smart electrical systems and electricity generation systems derived from RE sources (e.g. inverters, etc.), with the aim of ensuring safety and maintaining standards. However, the two distribution utilities lack a centralised mechanism for approving the list of such standardised products and equipment. The procedures for these two utilities are distinct.
3. Grid and transmission risk	• **Unawareness of the different distribution power utility grid codes.** Different grid code implementations result from the dissimilar topology and network utilisation of the distribution networks of two power utilities. However, both utilities can raise awareness and promote the process of connecting the solar PV system of end-users to the grid. • **Capacity constraints for connecting solar PV systems.** The hosting capacity of the grid is not disclosed by utility companies. Therefore, in order to verify hosting capacity at their connection points, consumers are required to pay a fee each time. Customers will be charged additional expenses to connect to the three-phase level mandated by the utilities if the capacity at the connection point exceeds the grid code limits.
4. Financial risk	• **Restrictions on access to financing and unattractive loan conditions.** Despite the presence of loan options for solar PV installations, lending standards remain rigorous with regard to the creditworthiness of borrowers for loan repayment. This may influence banks' credit risk assessments, resulting in increased loan rates as system proprietors' creditworthiness is diminished on the basis of their historical repayment records as opposed to project-specific risks. • **Exchange rate fluctuations affecting PV system costs.** The majority of solar equipment and panels are imported from other countries. Thus, the cost is contingent upon the prevailing exchange rate.
5. Developer risk	• **No review system for installer or developer companies.** Small developer/installer firms that lack experience and a track record of success may encounter challenges in completing rooftop solar projects due to financial management and capacity constraints. • **Uncertainties in Third-Party Ownership PPAs.** There is a possibility, under PPA contracts with developers, that the actual electricity demand of consumers will not correspond to the demand forecasted during the project assessment that preceded the settlement of the PPA. This discrepancy could result in the failure to collect anticipated revenues. Issues with property ownership can also affect third-party ownership PPAs. These could include conflicts of interest between existing lenders and PPA financiers, difficulties obtaining collateral owing to existing debts, or uncertain ownership rights that cause project approvals to be delayed. • **Additional unforeseen costs**, such as the cost of dealing with solar panels when reaching their end-of-life stages, might not be initially included in the feasibility analysis.

Risk	Underlying barriers
6. Hardware risk	• **Limited capacity of solar panel testing centres.** Due to substantial advancements in PV panel efficiency, large-scale utility solar systems that were previously installed may opt to replace their outdated technologies with newer ones. As a consequence, second hand PV panels have become readily available in the market. Nevertheless, the capacity of solar panel testing centres to examine panel quality is restricted. This could result in inferior panels being sold on the market. • **High cost of lithium-ion batteries.** Future risk exists if rooftop solar installation requires a lithium battery, as batteries may be prohibitively expensive.
7. Labour risk	• **Lack of expertise in solar PV installer companies.** For the design of rooftop PV systems, particularly for commercial and industrial segments, engineering expertise is typically required. In the absence of specialists, installation companies run the risk of producing substandard work and forgoing prospects to procure significant projects. • **Insufficient certified labour for PV installation.** Due to the abundance of training courses for PV system installation, there is ample labour. However, rooftop solar professionals do not have a specific certification to attest to their adherence to standards or ability to perform standardised installations. This will result in difficulties in dismantling the systems later.
8. Social perception risk	• **Misunderstanding and lack of knowledge in installing rooftop solar systems**, especially in the residential segment. Some people, for instance, believe that rooftop solar systems should not be installed on the structure of a typical home because they could potentially serve as lightning rods. Furthermore, there are individuals who hold the misconception that rooftop solar systems enable the use of solar energy during the night, even without the need for batteries, or that they will incur no electricity expenses (although this may not be the case).

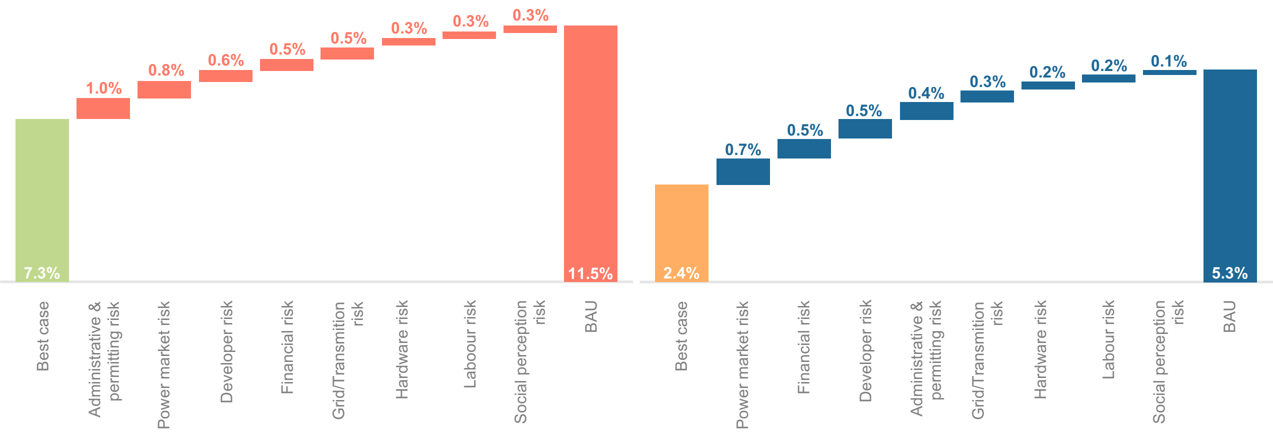
3.2 Impacts of risks on financial costs and LCOEs

Higher risks for rooftop solar PV installations could increase financial costs (i.e., cost of capital that consists of cost of equity and cost of debt) and hence the LCOE. We employed the Unites Nations Development Programme's 'Derisking Renewable Energy Investment' (DREI) framework to quantify the impacts of risks on financial costs using a risk waterfall analysis (see Annex 1 for more details).

A risk waterfall analysis quantifies the contribution of each risk category to the increased cost of equity and cost of debt for rooftop solar PV projects. Figure 3-1 shows the results of the impact of each risk category on the cost of equity and the cost of debt.

Figure 3-2 Risk waterfall for cost of equity and cost of debt

Cost of Equity	Cost of Debt



Top 3 risks

1. Administrative and permitting risk
2. Power market risk
3. Developer risk

These top 3 risks account for 57% of risk premium.

Top 3 risks

1. Power market risk
2. Developer risk
3. Financial risk

These top 3 risks account for 58% of risk premium.

The results from the risk waterfall analysis indicate that all eight risk categories could increase the cost of equity by 4.2% points and the cost of debt by 2.9% points.

Successful de-risking instruments for administrative and permitting, power market, and developer risks could reduce the financial cost of equity for rooftop solar PV investment by as much as 2.4% points.

Investors considering rooftop solar PV projects face various risks that can elevate their required rate of return, or cost of equity. Among these risks, the complex and time-consuming permitting process is considered the most critical, potentially increasing the cost of equity more than any other factor. This lengthy process delays project completion, hindering investors or system owners from earning a return on their investment and realising the benefits of solar energy.

Investors and system owners also value policies and incentives that encourage rooftop solar PV adoption. Existing policies that promote self-consumption without permitting excess electricity to be fed back into the grid, as well as net-billing schemes limited to residential consumers, do not appear to be sufficient. Financial incentives in the form of electricity buy-back programmes are attractive, but policies allowing excess solar energy to be fed back into the grid are equally important for achieving a quicker return on investment.

Finally, the absence of a review system for installers or developer companies, along with a lack of transparency regarding potential excluded costs, contributes to investor or system owner concerns about developer risks. Without a system for evaluating developer or installer qualifications, investors often favour large, well-established installer companies. This creates a barrier to entry for smaller, newer installer firms that may lack experience or a proven track record. Additionally, the potential for developers or installers to unintentionally omit lifecycle costs associated with system maintenance and decommissioning adds to investor uncertainty.

The top three risks associated with the financial cost of debt for rooftop solar PV investment are power market, developer, and financial risks. By successful mitigation of these risks, the financial cost could be reduced by as much as 1.7% points.

From a financial institution's perspective, the cost of debt for rooftop solar PV projects hinges on the perceived risks associated with the project's cash flow and the creditworthiness of the borrowers, which can include investors, system owners, and developers. Among these risks, power market risk emerges as the primary concern. Banks and lenders prioritise clear and stable policy frameworks (with minimal changes) to ensure a predictable return on investments. Complex installation rules and red tape limit project owners' potential benefits, affecting their cash flow and creditworthiness. Power market uncertainties further amplify risk by impeding innovation, technological advancement, and the development of new business models in the rooftop solar PV sector.

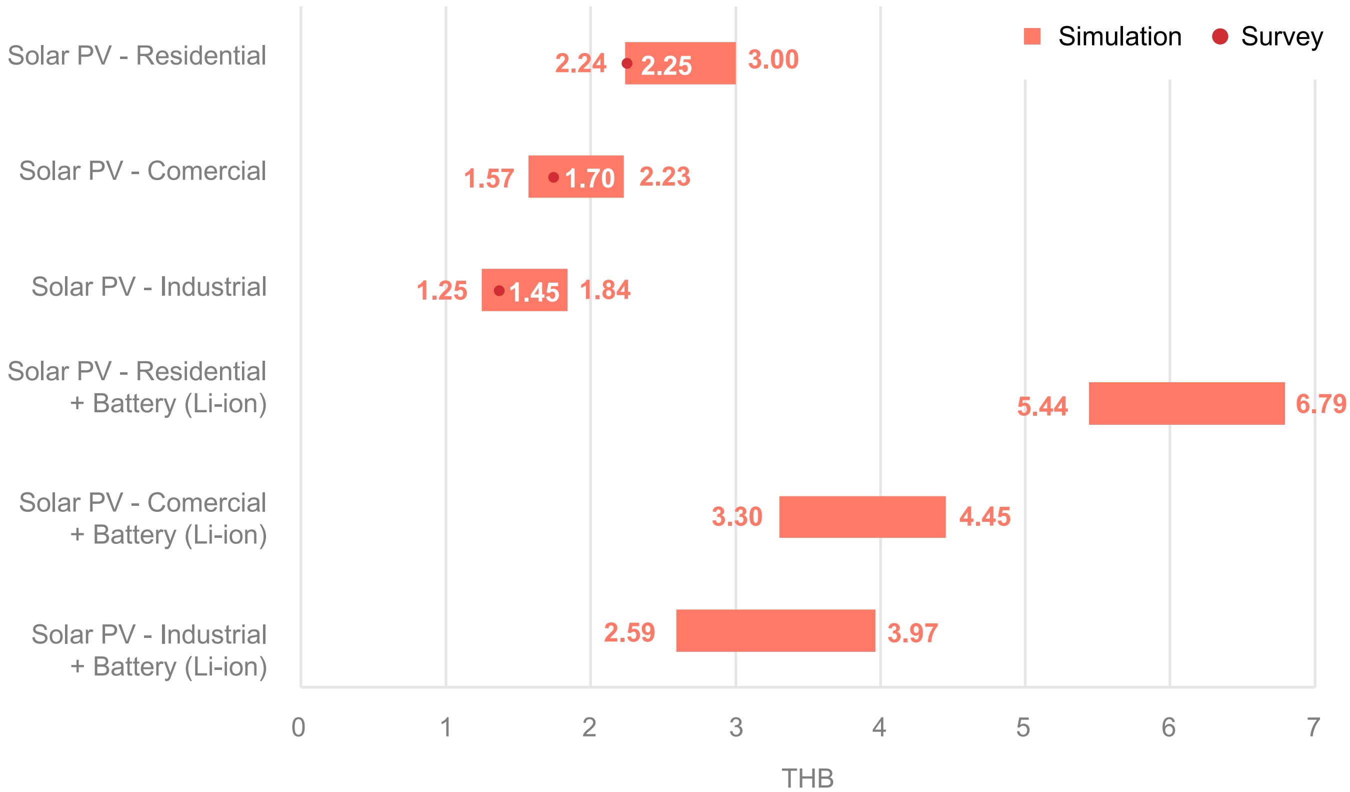
Financial institutions also express concerns regarding developer risks, particularly associated with new business models like third-party ownership PPAs for large-scale rooftop solar PV projects. Since such PPAs are customised to a customer's electricity consumption, developers offering them face the risk of the customer failing to meet their contractual obligations or experiencing lower than anticipated electricity demand. The third-party ownership PPAs can be complicated by property ownership issues. These might include conflicting interests between existing lenders and PPA financiers, difficulties securing collateral due to existing loans, or unclear ownership rights that delay project approvals.

Finally, financial institutions are wary of financial risks. Customers naturally prioritise access to loans with low interest rates. However, currently unattractive loan terms with limited durations, high interest rates, and restricted access to financing hinder rooftop solar PV adoption. Lenders, particularly when dealing with new or small installers/developers, often prioritise the borrower's repayment capacity over the project's cost-effectiveness or risk profile, raising concerns about loan reliability. Furthermore, the fluctuating exchange rate exposes projects to financial risk, as the reliance on imported solar equipment and panels makes project viability vulnerable to currency movements.

LCOE of residential, commercial, and industrial rooftop solar PV is currently grid parity, or competitive with the retail price of electricity purchased from the utility.

As of 2024, rooftop solar PV has achieved grid parity for all sectors in Thailand. This means the cost of generating electricity from rooftop solar PV (LCOE) is now competitive with the average retail electricity price, which currently ranges between 3.5-4.5 THB/kWh[9]. The LCOEs presented in Figure 3-2 were derived from two sources: (1) the mean survey data and (2) the simulation data. The mean survey data come from stakeholder participants in a focus group meeting. However, it should be noted that the survey data have limitations. The number of respondents is limited, and their responses did not specify financial sources, or the proportions of cash and loans used in their projects. On the other hand, the simulation data were generated through a simulation model using the assumptions outlined in the Annex 2. The simulated LCOEs[10] were calculated for rooftop PV investments financed with 100% equity and 70% loans. While grid parity has been achieved for rooftop solar PV systems alone, pairing them with lithium-ion batteries currently results in a less attractive LCOE. However, the commercial and industrial scales have achieved grid parity.

Figure 3-2 LCOE estimated for rooftop PV investments in Thailand[11]



9 Average electricity prices during Jan-Mar 2024 from ERC website (ERC, 2024)

10 The LCOE is calculated by taking into account all the costs associated with system, operating, and maintaining a power generation facility, and then dividing those costs by the total amount of electricity that the facility is expected to produce over its lifetime.

11 The upper and lower bound of simulated LCOEs were formed on the basis of the assumption that the investment would be made with 100% cash and 70% loan. Additional details regarding cost assumptions are provided in Annex 2. The surveyed LCOEs were compiled from 13 survey responses from the private sector and financial institutions.

3.3 Key risks and existing policy and financial de-risking instruments

With the current available self-consumption programmes, the adoption of rooftop solar PV systems is more appealing to commercial and industrial customers due to the substantial electricity bill reductions that can be achieved. Furthermore, tax incentives have been established to support solar PV installations by cooperatives. This self-consumption programme prohibits excess electricity from being fed into the power grid, thereby preventing solar PV from operating at full capacity. Under this self-consumption programme, for instance, industrial units that typically experience low loads at weekends may be required to install a smaller PV system in order to restrict surplus electricity at weekends, or an optimal PV size for serving loads during the week, and turning off excess electricity at the weekends. Therefore, large amounts of solar electricity remain unused, and utilising this untapped solar energy can increase the financial viability of the investment.

Residential customers encounter the identical problem of excess solar energy; however, residential customers face a unique challenge since they often generate more excess solar energy. This excess can create grid management issues if fed back in large quantities. Therefore, investigating additional buyback incentives for residential customers is crucial to achieve a balance that benefits both consumers and utilities. While the current buyback programme lacks clarity, new tax incentives are expected for residential solar power in the near future. However, the specific details of these incentives remain uncertain. Implementing clear buyback programmes or targeted tax breaks can encourage responsible residential solar adoption and mitigate potential grid disruptions caused by excess energy production.

Current self-consumption and residential solar programmes, which are accessible to all eligible customers, result in unforeseen connections between PV systems and the main power grid, thus introducing complexities in grid operation and management. These existing support programmes concentrate on alternatives for obtaining electricity. Nevertheless, design support programmes for solar power fail to consider the advantages of distributed PV in terms of grid management and the postponement of grid expansion.

Solar installation permits and administrative procedures continue to be cumbersome and time-consuming due to the need to acquire permits from several government agencies and the absence of a centralised facilitating platform. A lengthy administrative and permitting process implies PV system owners take longer to earn revenue or benefits from solar electricity. The ERC office has been developing a platform to streamline and expedite these procedures. Policymakers and power utilities will benefit from the streamlined procedure when it comes to obtaining data from behind-the-meter PV systems, which is crucial for infrastructure planning and grid operation.

Private banks in Thailand have progressively expanded loan programmes for rooftop solar PV installations to households, SMEs, and businesses as alternatives to self-financing. There are several options to explore, such as conventional home loans, which can sometimes be extended to cover the cost of a solar installation; loans for sustainable technologies, which are available from many banks and are designed to help people adopt sustainable technologies like solar panels; or solar-specific loans, which usually have lower interest rates and can be tailored to the needs of a rooftop solar PV project. These loan options provide greater flexibility for those interested in solar power. To ease the process for potential solar customers, many banks have partnered with solar installers or developers. This streamlined approach can make it easier to secure financing alongside choosing an installer. For private enterprises interested in the third-party ownership model, some Thai banks offer loan options specifically for private PPAs (Manager Online, 2021) with private companies. It should be noted that loan approval typically requires a strong credit history and evidence of financial credibility.

To summarise the status quo of policy and financial instruments, we categorised them according to the top three risks associated with the cost of equity and cost of debt as shown in Table 3-2.

Table 3-2: Summary of existing policy and financial instruments that could mitigate the top-three risks for cost of equity and cost of debt

Cost of Equity	Cost of Debt		Risk	Existing policy and financial instruments
	1	**Administrative & permitting risk**	Complex and time-consuming permitting process	• The ERC office has been developing a platform to streamline and expedite permitting process for all licensee, not just solar.
			Complicated standard certification or equipment registration.	• There are no policy or financial instruments exist to resolve this issue.
1	2	**Power market risk**	Uncertainty and lack of continuity regarding policies to support rooftop solar investments.	• The self-consumptions and residential solar programme have been implemented.
			Unattractive incentives and policies to support rooftop solar installations.	• The buyback rate for the residential solar programme was increased to 2.2 THB/kWh but is still below the electricity price throughout the year at 3.5-4.5 THB/kWh. • Initiatives of tax incentive for residential customer group install rooftop solar PV system.
			Lack of planning and cooperation among government agencies.	• There are no policy or financial instruments exist toresolve this issue.
			Insufficient support for innovation, technology, or new business models for rooftop solar.	• ERC initiated the sandbox programme, which permits the testing of novel energy concepts under lenient regulations.
2	3	**Developer risk**	No rating/review system for installer or developer companies.	• There are no policy or financial instruments exist to resolve this issue.However, private companies may publish testimonials, reviews, past projects or accomplishments on their media channels.
			Uncertainties in third-party ownership PPAs	• There are no policy or financial instruments exist to resolve this issue.
			Hidden costs such as the cost of dealing with solar panels when reaching their end-of-life stages excluded,	• There are no policy or financial instruments exist to resolve this issue.
3		**Financial risk**	Restrictions on access to financing and unattractive loan conditions.	• Thai banks have progressively expanded loan programmes for rooftop solar installations • A few Thai banks extend loans to private enterprises that express interest in implementing the third-party ownership model utilising private PPA • It should be noted that the credibility of applicants is a criterion for loan access.
			Exchange rate fluctuations affecting PV system costs.	• Private banks usually have Foreign Exchange (FX) hedging services. • It is possible that SME developer or installer firms are unaware of the services.

4 International cases on policy and financial de-risking instruments

Building on the risk assessment in the previous chapter, this chapter delves deeper into international experiences to understand how various financial and policy instruments have been employed to address these specific challenges. Although not explicitly identified in the initial assessment, grid/transmission risks poses a significant policy concern for higher levels of rooftop solar PV integration into the power grid. Accordingly, policy de-risking instruments for grid/transmission risk are also explored through international case studies in this chapter. Examining how other countries have addressed this growing concern becomes crucial as rooftop solar PV projects gain traction in Thailand.

4.1 Policy de-risking instruments

Power market risks and administrative and permit risks can be alleviated by policy instruments. Examples of key de-risking policy instruments are presented in Figure 4-1.

Figure 4-1 Key policy de-risking instruments

Summary and key takeaways from policy de-risking instruments:

Policy de-risking instruments play significant roles in alleviating power market risks and administrative and permit risks as follows:

- **Setting long-term rooftop solar PV targets** helps increase the consistency and continuity of compensation schemes under rooftop solar PV programmes, signalling the potential growth of rooftop solar PV investments in the country.
- **Well-designed rooftop solar PV programmes** not only reduce power market risks but could also help the government to achieve related policy objectives such as to reduce the adverse impacts of distributed energy resource integration upon grids and to ensure fair distribution of electricity fixed costs. The well-designed rooftop solar PV programme also includes appropriate compensation schemes such as net-metering, net-billing, and gross FIT, as well as direct capital subsidies. Emerging international trends indicate the evolution of compensation schemes from net-metering to net-billing and the inclusion of policy elements to encourage battery storage installations with rooftop solar PV, as well as new business models such as P2P and virtual net-metering.
- A dedicated **one-stop shop portal for rooftop solar PV** is key to help reduce administrative and permit risks with portal elements that streamline the permitting process and provide information about regulations, equipment standards, reliable vendor lists, and availability of financial sources.

The details of roles and international case examples of these key policy instruments are provided in Sections 4.1.1-4.1.3.

4.1.1 Long-term rooftop solar PV targets and well-designed rooftop solar PV programmes

Description and roles:

Setting long-term rooftop solar PV targets provides signals for investments and directions for policy support on rooftop solar PV projects, including the introduction of subsequent compensation schemes for rooftop solar PV projects and financial rebates supported by the government to achieve the targets. In addition, well-designed rooftop solar PV programmes will not only be critical for improving the investment environment for rooftop solar PV deployment but will also help the government meet other policy objectives (e.g. to ensure electricity supply with increased demand, avoid the risks of electricity shortages, reduce adverse impacts on grids, ensure fair distribution of electricity fixed costs, etc.). Despite the declining costs of PV installations, investment in rooftop solar PV projects for some client groups who do not consume power during the day may still have a long payback period or be less appealing than for groups that do use electricity during the day, such as commercial and industrial customers, so policy and financial incentives through rooftop solar PV programmes are necessary to facilitate the rooftop solar PV investments at the early stages of the deployment.

There are various policy and financial incentives for rooftop solar PV programmes, including net-metering or net-energy-metering (NEM), net-billing, buy all/sell all, or gross FIT as well as direct financial subsidies. The rooftop solar PV programmes normally specify the programme limit or maximum installed capacities of a rooftop solar PV system aligned with policy objectives and the eligible conditions and permits required. Setting rooftop solar PV targets and the availability of well-designed rooftop solar PV programmes in the country will play a significant role in reducing power market risks, thus increasing the feasibility of rooftop solar PV investments. The predictability of policies is key to mitigate risks as investors could calculate the amount of income over a certain period of time into the future for rooftop solar PV investment projects; hence, the projects will be less risky.

International case A: Rooftop solar PV targets and policies in India

Since 2015, India aimed to achieve 4.2 GW of rooftop solar PV capacity by 2019-2020, leading to the introduction of the Grid-Connected Rooftop Solar (RTS) programme Phase I with the financial incentives provided through a capital subsidy or Central Financial Assistance (CFA). However, the RTS programme Phase I was unsuccessful in boosting the rooftop solar PV installations as targeted due to the involvement of multiple agencies and stakeholders, a lack of uniform regulations, and lack of consumer awareness (Gulia, Gupta, Sharma, & Garg, 2023). In 2019, the RTS programme Phase II (2019-2026) was implemented with the aim of achieving a more ambitious cumulative rooftop solar PV capacity of 40 GW by 2022. As of 2022, the RTS programme Phase II had only achieved 8.1 GW of installed rooftop solar PV capacity, so the programme timeline was extended to March 2026 with the original approved budget of 1.43 billion USD. This RTS programme will also contribute to the government's target of 500 GW RE capacity by 2030. The RTS programme Phase II mainly provides a capital subsidy or CFA to residential electricity consumers for successful rooftop solar PV installations through 2 components (MNRE India, 2024):

- **Component A**: CFA to residential sector for 4 GW – A capital subsidy or CFA will be transferred directly to residential consumers with successful rooftop PV installation, applicable through the national portal for rooftop solar PV.

- **Component B**: Incentives to distribution companies (DISCOMs) for the achievement of the initial 18 GW capacity – Consumers will pay only the net amount after deducting the subsidy or CFA to a vendor after successful installation and verification by the State DISCOMs.

The incentives provided in Phase II (Table 4-1) aim to place distribution utilities or DISCOMs in a leading role to driving the rapid development of the RTS programme. A uniform and fixed CFA (e.g. up to 40% of the benchmark cost of the system) will be applicable under both components A and B as follows, with higher financial incentives for North-Eastern states based on their higher benchmark costs (Borah, 2023).

Table 4-1 Incentives under RTS programme Phase II in India

Types of residential consumers	For the entire country	For North-Eastern States*
Individual households	Rs. 14,588 INR/kW (for the first 3 kW) Rs. 7,294 INR/kW (for 3-10 kW)	Rs. 17,662 INR/kW (for the first 3 kW) Rs. 8,831 INR/kW (for 3-10 kW)
Resident Welfare Associations/Group Housing Societies (RWA/GHS)	Rs. 7,294 per kW (common facilities up to 500 kW and residences up to 10 kW each)	Rs. 8,831 per kW (common facilities up to 500 kW and residences up to 10 kW each)

In October 2022, the Ministry of New and Renewable Energy (MNRE) of India clarified that the subsidy or CFA under RTS Phase II will also be applicable for solar plants setup under the Virtual Net-metering (VNM) arrangement, subject to the following conditions: i) only for residential customers of rural areas, ii) each participating consumer with installed capacity of up to 3 kW, and iii) solar plant installed must supply power to the same distribution sub-station to ensure reliable power supply to the participating consumers and other benefits of co-locating power generation and consumption (MNRE India, 2022).

Gujarat, the leading state contributing to about 30% of India's total rooftop solar installation, highlights the following key success factors for the rooftop solar installation programme (SURYA Gujarat, 2023):

a) Policy relaxation such as no capacity restriction for installation of rooftop solar
b) Bulk purchase of bi-directional meters planned by DISCOMs
c) Large EPC vendors
d) Large number of consumers' participation with proactive awareness activities such as promotion through media
e) Single window portal with entire process completed via online portal
f) Performance based quota enhancement to vendors (e.g. quota extension allowed criteria)
g) State corpus fund
h) Task wise timeline (e.g. 3 days average timing for meter installation, 5 days for document verification, 18 days for payment, 22 days for work execution, etc.)

In January 2024, the Indian Government planned for a rooftop solarisation programme for households which will offer free electricity of up to 300 units every month and compensation for excess electricity output. The programme aims to significantly boost rooftop solar PV for residential users and to provide vendors with opportunities for increasing supply and installation as well as employment opportunities for manufacturing, installation, and maintenance (Kulkarni, 2024).

In India, inconsistent net-metering policies are implemented for commercial and industrial (C&I) consumers across states. Some states put restrictions for rooftop solar PV installations by C&I consumers such as restrictions on participation in net-metering, net-billing allowed with restrictions, levied grid charges, zero or low compensation for excess injection of solar power, etc. Several factors have hindered the growth of the C&I rooftop solar PV market, including the revision of the net-metering system cap from 1 MW to 500 kW, states shifting away from net-metering to net-billing, and the imposition of network charges for high-tension customers (Gulia, Gupta, Sharma, & Garg, 2023). The following emerging trends are expected to shape the rooftop solar PV situation in the C&I sector in India (Gulia, Gupta, Sharma, & Garg, 2023):

- **The adoption of battery storage in rooftop solar PV** is driven by increasing diesel costs, falling battery prices, restrictive net-metering policies, higher grid tariffs for C&I consumers, and the adoption of a time-of-day tariff structure expected in 2024.
- **The adoption of virtual net-metering** is driven by the smaller electricity needs of people living in semi-urban areas, the potential savings for businesses and large buildings with big rooftops and high energy use, and the ability to share solar power credits among multiple clusters, etc.
- **The adoption of P2P trading mechanisms** is driven by benefits to prosumers, such as freedom to choose an energy supplier, determined tariffs more attractive than net or gross metering, and to DISCOMs, such as reduction in distribution loss, rapid adoption of smart meters, stabilisation of voltage and reverse flow issues, balancing local generation and demand, etc.

International case B: Net-metering policies in the U.S.

In the United States, net-metering policies vary significantly across states, though in line with the Energy Policy Act of 2005, which marked a significant expansion of net-metering policies across states. Net-metering policies across states differ in terms of the programme characteristics (Gulia, Gupta, Sharma, & Garg, 2023) such as:

- **Individual system size cap** (kW): The maximum size of individual systems allowed for net-metering policies which range from 10 to 80,000 kW, or an unspecified cap.
- **programme size cap** (% peak of utility): The limit on the sum of allowed net-metering systems, calculated by the percentage of peak utility demand, which ranges from 0.5 to 100%, or unspecified cap.
- **Excess electricity compensation**: Compensation rate awarded to consumers for net excess electricity generation which includes the retail rate, avoided cost rate, and market rate.
- **Ownership of renewable energy credits (RECs)**: RECs can be awarded to consumers, utilities, or shared between consumers and utilities.

These programme characteristics indicated that the openness of the states to net-metering (such as high system size cap or high excess electricity compensation at a retail rate) signals a corresponding high percentage of net-metering customers and a long-lasting outcome of the net-metering policy (Smith, Koski, & Siddiki, 2021).

Hawaii, a leading state with a high percentage of net-metering customers compared to the total number of electricity customers, has set an ambitious goal to achieve the 100% clean energy goal by 2045, including the addition of nearly 50,000 rooftop solar PV systems across the islands by 2030. Accordingly, various private rooftop solar PV programmes are available in Hawaii (Hawaiian Electric, 2024) for new rooftop solar PV installations, incentivising battery storage and restricting export during certain times to ensure grid stability, including:

- **Customer Grid-Supply Plus (CGS Plus)** allows customers to install private rooftop solar PV or other renewables that export energy to the electric grid throughout the day. CGS Plus also requires the use of equipment that allows the utility to manage output to maintain safe, reliable grid operation. Customers receive a monthly bill credit for energy delivered to the grid, for example of CGS Plus Credit Rate: Oahu - 10.08 cents/kWh, Lanai - 20.80 cents/kWh, Molokai - 16.77 cents/kWh[12].
- **Smart Export** allows customers with a renewable system and battery ESS to export energy to the grid from 4 p.m. – 9 a.m. and receive compensation at a lower rate. Systems must include grid support technology to manage grid reliability and system performance.
- **Customer Self-Supply (CSS)** is intended only for private rooftop solar PV installations that are designed not to export any electricity to the grid. Customers are not compensated for any export of energy. PV customers with energy storage are eligible for an expedited review and approval of their systems in areas of high PV penetration.

These solar programmes closed to new customers on March 31, 2024. Following this, new Smart Renewable Energy programmes (so called **"Smart DER")** were introduced with simpler and more equitable programmes in the long term starting from April 1, 2024 (Hawaiian Electric, 2024). All participants are required to have an advanced meter and be enrolled in a *Shift and Save rate* (TOU rates encouraging more savings from the shift of energy use away from the high-demand evening and overnight hours that are at a higher kWh rate), a new pilot programme starting on February 2024 which is expected to be introduced to all customers in 2025. Smart DER aims to improve grid resilience, increase RE integration that is based on grid needs, and stabilise costs for all customers over time. Smart DER includes the following programmes:

- **Smart Renewable Energy Export programme**, replacing the previous CGS, CGS Plus, and smart export programmes, and offering new export rates available to all renewable technologies with no project size limits.
- **Smart Renewable Energy Non-Export programme**, optional for commercial rooftop solar PV customers under standard interconnection agreements (SIA) and residential rooftop solar PV under CCS programmes, allowing for all technologies and project sizes and with no exports allowed (no export bill compensation).
- **Bring Your Own Device (BYOD) programme**, a successor programme to the **Battery Bonus programme** that ended in December 2023**,** provide incentives for installing a new battery with an upfront capital subsidy of 100 USD (or maximum 500 USD for low-to-moderate income customers) for every kW committed to an existing or new rooftop solar PV system and a 5 USD bill credit each month for every kW committed for the 10 year-duration of the programme. The BYOD incentivises both new battery installation and its dispatch during specified time periods to help reduce the load and stabilise the grid.

[12] Average electricity price in Hawaii in 2023 ranges from 33 – 60 cents/kWh depending on the type of customers and the location (Hawaiian Electric, n.d.-a)

The significant growth of rooftop solar PV installation with over 60,000 customers installing systems in Hawaii was successfully driven by the NEM programme, which was suspended since 2015. Although only **NEM Plus** is currently available to present NEM customers, it is possible for customers to install new panels, battery storage or a combination of both under this programme. The output from the NEM Plus system is used solely on-site and is not allowed to be exported to the grid.

The rooftop solar PV programmes in Hawaii evolved from full incentives provided under the NEM towards more programme characteristics with a lower compensation rate, restrictions on export to the grid during certain times, and incentives provided for battery storage installations to ensure grid reliability and stability with higher levels of rooftop solar PV penetration.

Similarly, California's NEM policies have transitioned towards reduced compensation rates for solar energy fed back into the grid, and higher grid costs to reduce grid challenges and cost shift concerns from NEM policies. The **NEM 2.0**, the successor to the first NEM programme in California with the most successful rooftop solar PV installations, introduced non-bypassable charges for all electricity consumed, a one-time interconnection fee (e.g. a 800 USD fee for systems over 1 MW), and the requirement to take a time-of-use rate to reflect the actual cost of electricity during peak and off-peak times for programme participation to align the costs borne by NEM and non-NEM customers. The transition to **NEM 3.0** or the new net-billing tariff (NBT) resulted in a major reduction in export rates reflecting the value of generation to the grid (note: however, the value could also rise above the retail rate during late summer evenings), incentives for battery storage with solar installations, discouraging energy use at peak times and encouraging charging for electric vehicles and appliances at non-peak times (CPUC, 2021). The shift towards NEM 3.0 or net-billing was expected to slow down the adoption of solar systems in California (Exro, 2024).

4.1.2 One-stop shop for permits, streamline permitting process and equipment standards

Description and roles:

The main implementation barriers for rooftop solar PV programmes are often the involvement of several government authorities and complicated processes for permits, lack of consumer awareness on solar schemes, complex responses to applications on various queries, and a lack of knowledge about credible vendors and equipment standards as well as sources of financial support.

A dedicated one-stop shop portal for rooftop solar PV is therefore necessary to facilitate the installations of rooftop solar PV, removing the main implementation barriers with a streamlined permitting process and a single source of related information about regulations, standards, reliable vendor lists, and availability of financial sources. This one-stop shop portal could help alleviate administrative and permit risks for rooftop solar PV investments, particularly in the residential sector.

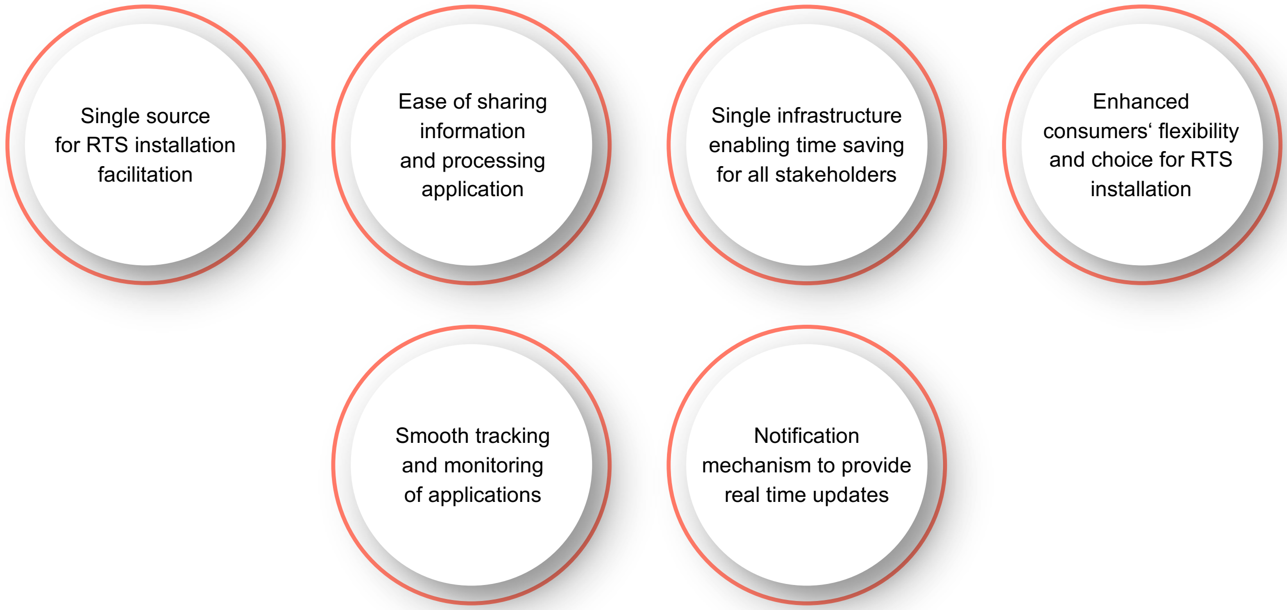
International case A: National portal for rooftop solar PV in India

The national portal for rooftop solar PV in India (MNRE India, 2024) plays an important role in facilitating rooftop solar PV installations in the residential sector in India. The MNRE of India launched the national portal for rooftop solar PV in 2022 to act as an e-marketplace, and an educational and awareness-raising space for consumers as well as a platform to provide information about rooftop solar PV such as the standards and specifications, rules and regulations issued by various authorities, the approved list of models and manufacturers (ALMM) for solar PV modules, and the list of registered vendors, etc. (Gulia, Gupta, Sharma, & Garg, 2023).

The national portal for rooftop solar PV (Figure 4-2) was developed to facilitate the installation of residential grid-connected rooftop solar PV projects with the following objectives (National Informatics Centre, 2023):

- Facilitate the ongoing scheme to achieve 40 GW of RTS installation by 2026
- To act as a single source to register and apply for residential RTS installation
- Streamline the process from application submission to the release of CFA directly to beneficiaries
- Provide flexibility to consumers to select empanelled vendors
- Simplify the application and enable necessary changes to edit requests
- Provide flexibility to DISCOMs to transfer the application to respective circle, division, and sub-division

Figure 4-2 Features of National Portal for Rooftop Solar in India



Source: Illustration from Gujarat Conclave, 2023

The national portal for rooftop solar PV in India (MNRE India, 2024) benefits all stakeholders, including beneficiaries (residential consumers), vendors, distribution companies (DISCOM), and the Solar Energy Corporation of India (SECI) which is the implementation entity under MNRE and MNRE of India as summarised in Figure 4-3. The national portal for rooftop solar PV also helps streamline the permitting process and provides information about requirements for equipment standards and a qualified vendor list.

Figure 4-3 Benefits of National Portal for Rooftop Solar in India

Beneficiary

- Office of Transport and Traffic Policy and Planning based quick register and login process
- Simplified procedure to submit rooftop application
- Easy tracking and editing of application

Vendor

- Flexibility to add rates (per kW) for installation of Solar Panels
- Option to choose respective districts for rooftop installations

DISCOM

- Quick feasibility approval & assign sub-office
- Ease of inspection approval
- Master module for Nodal Users, Circle, Feeder and Sub-Division details

SECI

- Bulk upload of verified final CFA list to Public Financial Management System (PFMS)
- Interface to verify & approve bank details for subsidy
- Quick rollback of application for "Payment Failed"

MNRE

- Multiple reports, charts and dashboard for real time data
- Tracking of application's latest status
- Monitoring the overall movement of applications

Source: Gujarat Conclave, 2023

4.1.3 Hosting capacity and grid code modifications

The hosting capacity and grid code modification will help alleviate grid risks, ensuring the smooth integration of higher levels of rooftop solar PV penetration without adverse impacts on the grid, thus ensuring grid reliability. The disclosure of hosting capacity could help reduce the negative impact of adding too much distributed generation without planning for appropriate upgrades to the grid infrastructure.

Description and roles:

The impacts of integrating higher levels of rooftop solar PV installations at consumer sites or distributed generation may impose grid and transmission risks for utilities. The availability of hosting capacity information will allow utilities, solar contractors, and customers to know the number of rooftop solar PV systems that can be accommodated on the distribution system at a given location under existing grid conditions and operate safely and reliably without the need for system upgrades. The hosting capacity information will benefit both consumers and utilities through full potential benefits of distributed energy resources such as rooftop solar PV generation on the grid (IREC, 2017).

In addition to hosting capacity, the modification of grid code regulations could play an important role in facilitating the integration of distributed energy resources such as rooftop solar PV, ensuring the stability and reliability of the grid through technical standards and regulation requirements. Key grid code requirements for distributed energy resources include: i) voltage and frequency regulations; ii) power quality and harmonics; iii) grid connection and disconnection such as requirements for anti-islanding protection and fault ride-through capabilities, and iv) grid monitoring and communication such as real-time grid information and seamless integration with existing infrastructure (IEEE, 2023).

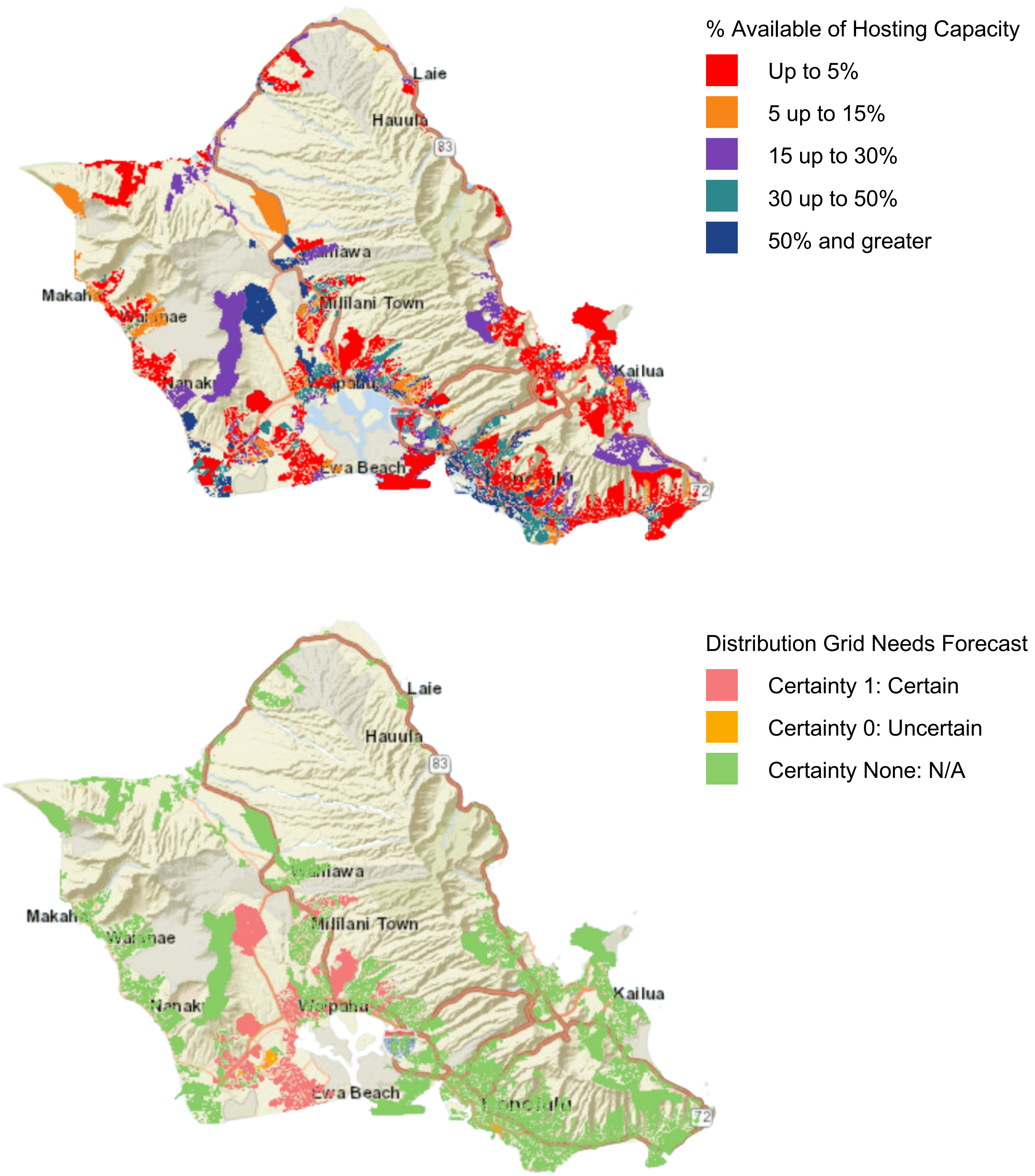
The hosting capacity and grid code modification will help alleviate grid risks, ensuring smooth integration of distributed energy resources with increased reliability and grid stability.

International case A:
The locational value map in Hawaii – hosting capacity information

A higher level of distributed generation (e.g. from private rooftop solar PV) connected to the grid may affect the reliability of the gird if there are not adequate protective measures put in place. In Hawaii, the publicly available locational value maps help customers and solar contractors to plan for customer-sited generation, indicating the amount of distributed generation hosting capacity remaining on the utilities' primary network. This could help reduce the negative impact of adding too much distributed generation without planning for appropriate upgrades to the grid infrastructure.

Figure 4-4 shows the percentage of remaining space currently available for solar on the primary circuit based on hosting capacity analysis (i.e., % available hosting capacity). If the percentage of available hosting capacity is less than 5%, this will require an interconnection study. So, whether an interconnection study or upgrades may be necessary depends on the level of percentage availability. In addition, it also shows areas on the electrical grid with future grid needs, depending on the certainty of future loads; for example, a certainty rating of 1 means a grid need is identified within the next 5 years that includes new service requests (i.e., future loads).

Figure 4-4 Example of the locational value map in Hawaii



Source: (Hawaii Electric, 2024)

4.2 Financial de-risking instruments

Financial risks and developer risks can be alleviated by financial instruments. Examples of key financial de-risking instruments are presented as shown in Figure 4-5.

Figure 4-5 Key financial de-risking instruments

Summary and key takeaways from financial de-risking instruments:

- Carefully designed financial de-risking measures can help to considerably lower financing costs for residential and commercial rooftop solar PV expansion. This in turn can also help attract private investors and lenders. Financial de-risking measures should not be looked at in isolation but can potentially be more effective if combined with other (financial and/or public) tailored de-risking measures that address the root causes of (perceived) higher financing costs in Thailand.
- Table 4-3 provides an overview of financing de-risking instruments and their respective merits.
- Moreover, there are direct financial incentives like tax credits that can serve as supplementary mechanisms (though not inherently de-risking tools) to enhance appeal for (commercial) financial entities. Additionally, while not inherently de-risking measures, blended finance can also assist in managing financial risks and might be worth considering in a broader sense.

Table 4-3 Potential benefits of financial de-risking instruments

Instrument	Benefits
Public guarantees	Helps ensure that in the event of any disruption in the payment capacity of a RE project developer, the payment obligation will still be met to creditors, wholly or partially.
Concessional loans and specific credit lines	Through the provision of concessional loans by public actors to commercial banks who could on-lend to project developers or homeowners, they help reduce the financial burden, extending repayment periods, providing grace periods, offering flexible repayment terms, supporting capacity building, and mitigating risks through government backing. This improves the financial viability of solar PV installations and can help attract additional investment.
Green bonds	Green bonds may be used to finance residential solar PV installations, while also providing a fixed rate of return. Can be useful to amplify the investor base and also to improve credit worthiness (due to the stringent due diligence/ evaluation process around green bonds) which in turn helps improve loan conditions.
Solar-specific insurance	Specialised insurance policies for solar PV installations. These policies can help to de-risk the investment by covering losses or damages to the solar panels or associated equipment, as well as liability in case of accidents or injuries.
Sustainability linked loans	The aims of this financial de-risking instrument are to increase projector accountability and to incentivise them to deliver good and sustainable outcomes. Therefore, it can increase the effectiveness of the project as well as its efficiency.
FX hedging programme/ facility	Use of a currency hedge for protection against devaluations in form of a public grant or subsidy.

The details of roles and international case examples of these key financial de-risking instruments are provided in Section 4.2.1-4.2.5.

4.2.1 Public financial guarantees

Description and roles:

Public financial guarantees serve to ensure that in the event of any disruption in the payment capacity of a RE project developer, the payment obligation will still be met to creditors, wholly or partially. The guarantee is thereby provided by the government or (international) development bank. There are different types of public financial guarantees, including loan guarantees, but also support for (RE) development policy operations or budgetary support.

Public financial guarantees can also take the form of risk-sharing arrangements, including risk-sharing facilities, where the risk of lending or investing is shared between different parties. A bilateral loss-sharing agreement is usually set up between a public actor and a (commercially oriented) financial institution.

International case A: ADB Rooftop Solar PV Investment programme

The Asian Development Bank (ADB) has introduced a Sovereign Guaranteed Rooftop Solar PV Investment Programme (SRIP), which has been implemented in response to the demand from Punjab National Bank, an Indian public sector bank under the ownership of the Ministry of Finance.

Under this programme, India has extended a sovereign financial guarantee to the ADB to support the SRIP's objectives. The primary goal of SRIP is to facilitate the financing of large rooftop solar PV systems on industrial and commercial buildings. These systems can operate either on a standalone basis or be grouped together in an aggregated manner.

SRIP has contributed to a substantial increase in debt funding directed towards the rooftop solar PV sector, amounting to 10 million USD in the first tranche. Moreover, with the support of technical assistance, the programme has also contributed to an increase in institutional capacity.

One of the key achievements of SRIP is the development of essential infrastructure within the rooftop solar PV market. The establishment of a robust bankable subproject pipeline has been instrumental in fostering a conducive environment for growth. The demand for rooftop solar PV systems has surged significantly, reaching a capacity of 745 MW. To facilitate accessibility and information dissemination, dedicated rooftop solar PV web portals have been successfully established (ADB, 2016).

International case B: The Africa Energy Guarantee Facility

The Africa Energy Guarantee Facility (AEGF) has created a risk-sharing platform to de-risk RE development, including solar PV. It focuses primarily on commercial RE development in sub-Saharan Africa and increasing the availability and access to long-term insurance capacity for energy projects.

The facility is composed of two developing finance institutions (European Investment Bank and Kreditanstalt für Wiederaufbau) that provide a 2nd loss guarantee and a commercial re-insurer. With the involvement of development finance institutions, the reinsurance capacity of commercial re-insurers is increased and extended to primary insurers. This empowers primary insurers to provide lenders and investors with solutions backed by the AEGF, enhancing their ability to effectively manage risks and timeframes associated with green energy projects. The better availability of suitable and affordable insurance motivated both lenders and investors to confidently fund solar PV development (AEGF, 2021).

4.2.2 Concessional loans and specific credit lines

Description and roles:

Concessional loans describe a type of financing with more favourable financing conditions than market ones. Concessional loans usually offer interest rates below the standard market rates or extended grace periods, or both. Concessional loans could be extended by public actors, such as governments or international finance institutions, to commercial banks who could on-lend to project developers or directly to homeowners, potentially with more favourable terms. This instrument could also be combined with public guarantees.

Specific credit lines describe a financing line specifically designed for a certain purpose, in this case residential and/ or commercial solar PV. These credit lines can offer flexible loan terms and competitive interest rates, making it easier for homeowners to afford the upfront costs of installing solar panels. Specific credit lines are usually provided by (international development) financial institutions to individuals or businesses.

International case A: World Bank support to India's residential rooftop solar PV sector

Traditionally, in India, residential consumers pay lower electricity rates compared to their commercial and industrial counterparts. This has resulted in less motivation for the transition to rooftop solar PV. This challenge is further exacerbated by factors such as the availability of affordable financing, innovative business models, and the significant upfront costs associated with solar adoption.

Therefore, in 2022, the World Bank approved a 165 million USD loan to support residential rooftop solar PV development in India. The primary objective of this support was to extend concessional financing to both developers and residential consumers, thereby facilitating the mobilisation of additional private capital.

In addition to supporting residential rooftop solar PV adoption, the project was geared towards assisting DISCOMs in their efforts to identify optimal groups of residential customers and suitable locations for the installation of rooftop solar PV and battery ESS. This aims to enhance the overall efficiency and effectiveness of RE integration within the national grid (World Bank, 2022).

4.2.3 Green bonds and sustainability linked loans

Description and roles:

Green bonds are a fixed income instrument where the issuer commits to using the green bond proceeds to finance or refinance green projects. Green bonds may be used to finance residential solar PV installations, while also providing a fixed rate of return. For de-risking, we refer to green bonds issued by public actors, especially governments and/or development banks (Braga, Semmler, & Grass, 2021).

Sustainability-linked loans are another debt instrument whose coupon is linked to the issuer's sustainability performance. Sustainability-linked loans are not yet widely used for de-risking. In principle, governments and (public) financial institutions could offer these loans to spur solar PV development given the borrower's lower risk of default while also stimulating sustainable practices.

International case A: Green bonds in Malaysia, Indonesia, and Singapore

Green bonds are increasingly being used in Malaysia, Indonesia, and Singapore to finance solar PV development (Azhgaliyava, Kapoor, & Liu, 2020). While the adoption of green bonds for such projects is still relatively modest and with green bonds primarily used in the building sector, there is nonetheless a growing trend in the region to also use green bonds to spur RE and solar PV development, which is spearheaded by Indonesia. In 2018, Thailand also issued a climate bond, a specific type of green bond, to finance solar PV (Nhede, 2019).

Green bonds are so far primarily issued by corporations and therefore have been mostly relevant for commercial and industrial solar PV development, but also bear potential for residential PV development, as described above (Azhgaliyava, Kapoor, & Liu, 2020; IRENA, 2020).

4.2.4 Solar specific insurance solutions

Description and roles:

Solar-specific insurance solutions describe policies that can help to de-risk the investment by covering losses or damages to the solar panels or associated equipment, as well as liability in the case of accidents or injuries. They are usually provided by commercial insurance providers but could also be provided by public actors to further support the growth and development of solar PV. Solar-specific insurance solutions are available to both project developers and businesses as well as homeowners.

International case A: Residential solar PV insurance solution in Malaysia

Several commercial insurance companies are now offering tailor-made insurance solutions designed for private owners of residential PV rooftop installations.

These solutions aim at tackling the specific challenges confronting solar PV owners, aiming to extend coverage that encompasses potential system damages, financial losses arising from system downtime, and unforeseen interruptions in energy production.

For example, in 2021, Malaysian enterprise Solaroo Systems Sdn. Bhd. and Allianz General Insurance Company Malaysia recently set up a partnership to spur solar PV development in Malaysia. This alliance has led to the incorporation of Allianz General's SolarPro insurance within Solaroo's operation and maintenance packages for residential solar PV systems, serving as a concrete example of how insurance companies are enhancing support for the solar sector (Solaroo, 2021).

[13] The current status of the facility is unclear.

4.2.5 FX hedging

Description and roles:

Foreign exchange (FX) hedging is a currency risk management strategy which businesses and financial institutions that operate internationally can use to protect their investments against fluctuations on the foreign exchange market (e.g. exchange risks, interest rate risk, etc.). In the solar PV development context, the protection against devaluation could take the form a public grant or subsidy that is extended to internationally operating project developers or financiers.

International case A: FX hedging facility in India

In India, the competitiveness of RE in the market is hampered by the scarcity of appealing debt options. Domestic debt comes with elevated costs, brief repayment periods, and fluctuating interest rates, thereby increasing RE costs by approximately 30% compared to similar projects in other regions. The expense of foreign debt is equivalent to domestic debt due to the need for costly market-based currency hedging methods (Farooquee & Shrimali, 2016).

An FX Hedging Facility[13] was therefore set up which operates under a government-backed scheme that subsidises a specific portion of FX risk, which is customisable to meet the specific needs of businesses operating in India. This facility was designed for both debt and equity structures, providing a mechanism for managing currency risk. Beyond its primary purpose, this facility helps reduce counterparty credit risk and liquidity risk, as well as enabling more precise allocation of public grants or subsidies by targeting a defined segment of the currency risk.

The FX Hedging Facility aims to benefit both donors and users. In instances where currency depreciation is milder than anticipated, the facility captures the positive variance, which can be later transferred to donors or users. This approach optimises the deployment of donor capital in contrast to commercial currency swaps, thus enhancing the efficiency of the overall system (Climate Policy Initiative, 2020).

5 Conclusions and recommendations

Thailand has introduced several policy and financial incentives to foster rooftop solar PV deployment since 2019, particularly a net billing programme for residential consumers and several P2P energy trading pilots under the ERC sandbox initiatives. Despite a surge of rooftop solar PV installations in 2023, driven by high electricity prices, the current adoption rate of rooftop solar PV systems in Thailand is still much lower than its huge potential. This is due to several policy, regulatory and financial risk barriers. This study systematically identifies the risks for rooftop solar PV investment in Thailand and quantifies these risks' impacts on financial costs. Finally, the study highlights appropriate policy and financial de-risking instruments that can support rooftop solar PV deployment in Thailand. Key findings and recommendations from the study are as follows:

1. Policy and financial instruments for addressing administrative and permitting, power market, developer, and financial risks should be put as priorities in reducing financial costs of rooftop PV investments in Thailand.

De-risking instruments mitigating administrative and permitting, power market and developer risks could reduce the cost of equity of rooftop solar PV investments by as much as 2.4% points. On the other hand, power market, developer, and financial risks are top-three risks contributing to higher costs of debt, and mitigating these could lower the cost of debt by as much as 1.7% points. All together, these four risk categories altogether account for about 57% of total risk premiums. Other risks investigated included grid and transmission, hardware, labour and social acceptance risks.

Figure 5-1 summarises main risk categories associated with rooftop solar PV investments in Thailand and possible policy and financial de-risking instruments for each risk. Several de-risking instruments have already been implemented in Thailand; however, there remains significant room for improvement building on international examples.

Figure 5-1 Policy and financial instruments for top-three risks for cost of equity and cost of debt

Key risks	Administrative & Permitting risk	Power market risk	Developer risk	Financial risk
Possible financial cost reduction for cost of equity	1.0%	0.8%	0.6%	
Possible financial cost reduction for cost of debt		0.7%	0.5%	0.5%
Policy instruments	• One-stop shop for permits • Streamline permitting process	• Long-term rooftop solar targets • Well-designed rooftop solar programme		
Financial instruments			• Solar-specific insurance solutions • Concessional loans/specific credit lines	• Public financial guarantees • Risk sharing facility • Concessional loans/specific credit lines • Other financial instruments (Green bonds, Sustainability-Linked Bond)

Green = In progress,
Blue = Exists,
Yellow = Does not exist

2. Developing a one-stop shop or centralised platform that simplifies permitting, streamlines equipment registration, and offers online application process could significantly boost rooftop solar adoption by reducing administrative and permitting costs, improving forecasting accuracy, and easing processes for all stakeholders.

Addressing the sources of administrative and permitting risks could lower the cost of equity by about 1% point. The current lack of centralised equipment standardisation means that vendors must navigate a complex set of different procedures to register the inverters and other components used in smart electrical and RE systems.

The ERC's initiative to develop a platform for streamlining and expediting permits across the electricity industry is therefore an important step in the right direction and could also help reduce the number of unregistered rooftop solar PV systems arising from frustrations with the complex permitting procedures. Such unregistered rooftop PV systems pose additional risks to system operators. For example, unreported self-consumption loads could lead to inaccurate electricity consumption forecasts and could disrupt grid management.

A key solution to addressing these challenges, could be to expand the development plan for ERC's platform to go beyond simply streamlining permits. This platform could evolve into a one-stop shop or centralised platform[14] for permits that offers a simplified process for online applications, alongside a consolidated information repository that includes a list of qualified equipment standards. For rooftop solar PV vendors, the platform could include a list of available financial products such as appropriate loans offered by financial institutions, real-time updates for new policy incentives and regulations, and a system to tracking and monitoring applications. India's National Portal for rooftop solar PV exemplifies how a one-stop-shop platform could accelerate rooftop solar PV initiatives. Such a system would benefit all stakeholders by reducing the time and costs for acquiring permits will also reducing associated developer and financial risks. Policymakers and utilities would benefit from better forecasting accuracy and more available data on registered solar systems. Solar system owners would benefit from a speedier and less complex permitting procedure and so would avoid unnecessary delays and hassle. Finally, suppliers would benefit from expedited registration procedures due to uniform equipment requirements, which would reduce administrative constraints and speed up product rollout.

In addition, the publicly available data on "hosting capacity" — the ability of the grid to accommodate additional solar power in a specific location without the need for upgrades — is crucial for utilities, solar contractors and consumers to ensure a technically sound integration while attracting consumer participation with less administrative costs and time saved for individual interconnection studies.

3. Developing long-term rooftop solar PV targets and well-designed rooftop solar programmes that are consistent with grid planning should be prioritised to mitigate power market risk and benefit from the flexibility of demand response from distributed generation.

[14] The ownership and responsibility of the centralised platform can be determined at a later stage.

Aligning long-term rooftop solar PV targets and support programmes with grid planning can mitigate power market risks while unlocking the potential of distributed energy resources, including energy storage, to provide flexible system services through demand response.

Power market risks, particularly those arising from an inconsistent (stop-and-go) policy support combined with inadequate incentives such as those under existing rooftop solar PV programmes, present significant barriers for rooftop solar PV investment. These barriers increase the cost of debt and equity by as much as 0.8% and 0.7% points, respectively.

Currently, Thailand employs a net-billing scheme for rooftop solar PV for residential consumers which aims to procure 90 MW between 2021-2030[15] (ERC, 2023). The net-billing scheme, which deploys a relatively low buyback rate of 2.2 THB per kWh, has so far failed to significantly increase investments. In fact, the 2023 surge in residential PV installations was driven predominately by high electricity prices, rather than buyback incentives. In addition, no such targets or incentives exist for commercial or residential consumers, who contribute around 66% of power demand in Thailand. Currently, commercial and industrial consumers are unable to export electricity to the grid, so rooftop PV can only be used for self-consumption.

To address such challenges, Thailand could consider setting **proactive long-term targets for rooftop solar PV** deployment that are supported by rooftop solar PV incentive programmes for all **residential, commercial, and industrial consumers**. Such incentive **programmes** would not only reduce power market risks but could also **stimulate the deployment of new technologies**, such as energy storage paired with rooftop solar systems, to enhance grid flexibility by reducing peak demand and optimising grid utilisation. By carefully designing these incentives, policymakers, regulators, and utilities can collaboratively unlock the potential of demand response from distributed energy resources to address the increasing electricity demand from transportation and industrial electrification. Aligning long-term targets and incentives with grid planning is crucial for **maximising these benefits** and ensuring a resilient and sustainable power system

The **design of rooftop solar PV programmes** could be tailored to meet several policy objectives while offering attractive benefits to consumers. Several examples from Smart DER programmes in Hawaii illustrate how such programmes can improve grid resilience by enabling solar PV integration based on grid needs while also stabilising prices for all customers. These include **capital subsidies** (e.g. direct financial assistance or tax breaks) for **low-income households** (or low installation capacity of less than 3 kW, like in India), capital subsidies for **battery installations** to existing and new rooftop solar PV systems, and **rate incentives** to shift electricity use away from peak demand periods and compensation for battery storage discharges. In addition, the rooftop solar PV programmes could set system capacity limits or programme size caps to prevent oversubscription and to mitigate the risk of grid disruptions.

As of 2024, Thailand's DEDE is proposing an additional financial incentive to the existing net-billing scheme for households. The incentives would provide a **tax reduction** for rooftop solar PV installations less than 10 kW at a cost of less than 200,000 baht. This new scheme targets 90,000 households and is expected to reduce electricity consumption from the grid by 585 million kWh per year (or ideally equivalent to a reduction of 9,000 tonnes of liquefied natural gas (Praiwan, 2024). An additional programme that DEDE could also consider are additional incentives for low-income households or those with rooftop solar PV installations less than 3 kW. DEDE could also initiate **targets and incentive programmes targeted at commercial and industrial consumers**.

[15] ERC Announcement: Invitation to Sell Rooftop Solar Electricity for Residential Customers (No. 2, 2023)

4. To reduce developer risks, Thailand should prioritise policies that enhance developer transparency, mitigate financial risks associated with PPAs, and establish a clear pathway for solar waste management and potential second-life markets.

Developer risks which encompass lack of experienced and qualified installers, uncertainties in third-party ownership PPAs, and unforeseen costs, pose significant challenges for both investors and financial institutions. Effectively mitigating such risks can reduce the cost of equity and the cost of debt by up to 0.6% and 0.5% points, respectively.

One option to reduce developer risks is to promote reliable **review platforms** for solar companies where consumers can easily identify reliable installers and so mitigate some of the risks leading to delayed or unfinished projects by unreliable contractors. Installers and developers help mitigate developer risks from third-party ownership PPAs by **exploring partnerships with financial institutions** for credit checks on potential clients and **implementing strategies** to mitigate customer non-payment risks, such as establishing clear non-payment thresholds or demountable PV installations for a second-life PV market. Policymakers should establish a clear timeline and direction for **solar waste management** while also exploring the viability and market potential for used solar panels. This would reduce uncertainty for businesses and allow them to better plan for the end-of-life phase of PV systems.

5. Financial de-risking instruments could play crucial roles to reduce costs arising from limited access to financing, unattractive loan conditions, and lender risk aversion.

Financial risk, one of the top three most significant risks associated with rooftop solar PV investment in Thailand, is likely to stem from unattractive loan terms, lender's singular focus on repayment, and volatile exchange rates. If this risk is mitigated, the cost of debt could decrease by as much as 0.5% points. Several financial de-risking instruments could be developed through **collaboration between financial institutions and government agencies**.

Financial institutions and government agencies responsible for solar initiatives could co-develop **tailored financial solutions for rooftop solar PV projects**. These solutions could include loan guarantees, partial risk guarantees, first-loss guarantees, and innovative currency hedging products. In addition, by collaborating with solar installers, specific loan programmes could be tailored for rooftop solar PV projects, which offer **more favourable interest rates and longer loan terms** that reflect the specific cash flow patterns of solar energy generation. Furthermore, collaboration between solar installers and insurance companies could enable **new specific insurance** solutions that cover losses or damages to solar panels and associated equipment, thereby reducing the risks arising from interruptions in energy production (as implemented in Malaysia). Meanwhile, the development of a currency (FX) hedging facility may be too early for implementation in Thailand, but has demonstrated success in India.

The collaboration between financial institutions and government agencies could also extend to cover the **development of risk-sharing mechanisms**, such as loan guarantees or performance-based incentives, which reduce perceived risk for both parties. The Bank of Thailand can play a crucial role by issuing **guidelines for loan risk assessment** that incorporate project-specific factors for rooftop solar PV projects. This would encourage lenders to move beyond just credit history, leading to a more comprehensive evaluation and potentially more favourable loan terms for solar projects.

References

ADB. (2016, November). *India: Solar Rooftop Investment programme*. Retrieved from ADB: https://www.adb.org/projects/49419001/main#:~:text=The%20proposed%20%24505%20million%20sovereign-guaranteed%20Solar%20Rooftop%20Investment,and%20a%20%245%20million%20capacity%20development%20technical%20assistance

AEGF. (2021, June). *The AEGF Ecosystem*. Retrieved from African Energy Guarantee Facility: https://www.aegf.net/aegf-ecosystem.html

African Guarantee Fund. (2023). Retrieved from https://africanguaranteefund.com/african-guarantee-fund-and-empower-new-energy-partner-to-boost-africas-solar-industry/

Azhgaliyava, D., Kapoor, A., & Liu, Y. (2020). *Green bonds for financing renewable energy and energy efficiency in Southeast Asia: A review of policies.* Asian Development Bank Institute (ADBI). Tokyo: Asian Development Bank Institute. Retrieved from https://www.adb.org/sites/default/files/publication/562116/adbi-wp1073.pdf

Bangkok Bank. (2021, March 4). *Bualuang Green Loan (in Thai)*. Retrieved from Bangkok Bank: https://www.bangkokbank.com/th-TH/Business-Banking/Finance-My-Business/Loans-for-SMEs/Bualuang-Green-Loan

BOI. (2024, March 28). *Thailand BOI Approves Measures to Support Carbon Reduction*. Retrieved from https://www.boi.go.th/index.php?page=press_releases_detail&topic_id=129254

Borah, H. C. (2023, January 27). *Office Memorandum: Admissibility of CFA for residential sector rooftop solar projects installed under Rooftop Solar programme Phase-II.* Retrieved from S3WaaS – Secure, Scalable and Sugamya Website as a Service: https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/01/2023012761.pdf

Braga, J. P., Semmler, W., & Grass, D. (2021). De-risking of green investments through a green bond market- Empirics and a dynamic model. *Journal of Economic Dynamics and Control, 131*, 104201. Retrieved from https://www.sciencedirect.com/science/article/pii/S0165188921001366

CASE. (2022). *Towards a collective vision of Thai energy transition: National long-term scenarios and socioeconomic implications.* Bangkok: Clean, Affordable and Secure Energy for Southeast Asia. Retrieved from https://caseforsea.org/post_knowledge/full-report-towards-a-collective-vision-of-thai-energy-transition-national-long-term-scenarios-and-socioeconomic-implications/

Chaianong, A., Bangviwat, A., Menke, C., Breitschopf, B., & Eichhammer, W. (2020, February). Customer economics of residential PV–battery systems in Thailand. *Renewable Energy, 146*, 297-308. Retrieved from https://www.sciencedirect.com/science/article/pii/S0960148119309991

Climate Policy Initiative. (2020, July). *FX Hedging Facility*. Retrieved from Climate Policy Initiative: https://www.climatepolicyinitiative.org/wp-content/uploads/2020/07/FX-Hedging-Facility_Instrument-Overview.pdf

CPUC. (2021, August). *Customer-Sited Renewable Energy Generation.* Retrieved from CPUC: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/net-energy-metering

EGAT. (2022, November 2). *Thailand's 1st I-REC Standard Conference 2022 to accelerate green energy market for ASEAN sustainability*. Retrieved June 4, 2024, from EGAT I-REC ISSUER: https://*www.egat.co.th/home/en/20221102e-02/*

EM Energy. (2023, June 23). *Installing Solar Cell Systems for Businesses with Rooftop Solar Loans (in Thai)*. Retrieved from EM Energy: https://www.emenergy.co.th/%e0%b8%aa%e0%b8%b4%e0%b8%99%e0%b9%80%e0%b8%8a%e0%b8%b7%e0%b9%88%e0%b8%ad%e0%b9%82%e0%b8%8b%e0%b8%a5%e0%b9%88%e0%b8%b2%e0%b8%a3%e0%b8%b9%e0%b8%9f%e0%b8%97%e0%b9%87%e0%b8%ad%e0%b8%9b/#:~:text=%E0%B8%AA%E0%B8%B4%E0%B8%99%E0%B9%80%E

EPPO. (2023, February 20). *New S-Curve (in Thai)*. Retrieved from EPPO: https://www.eppo.go.th/index.php/th/component/k2/item/19212-news-170266-01

ERC. (2022, September 30). *Procurement of electricity from renewable energy in the form of Feed-in Tariff (FiT) 2022 - 2030 for groups with no fuel costs (in Thai)*. Retrieved from ERC: https://www.erc.or.th/th/power-purchasing3/2697

ERC. (2023). *Rooftop Solar Power Generation Project for Residential Customers (in Thai).* Retrieved from ERC: https://www.erc.or.th/web-upload/200xf869baf82be74c18cc110e974eea8d5c/tinymce/21-39bfd379b4b71c8e2563cfce47473c60/โครงการ%20Solar%20Rooftop%20ภาคประชาชนประเภทบ้านอยู่อาศัย/ประกาศ%20กกพ.%20เรื่อง%20ประกาศเชิญชวนการรับซื้อไฟฟ้าโครงการผลิตไฟฟ้าจากพลังงานแสงอาทิตย์

ERC. (2024). *Electricity service rates (in Thai)*. Retrieved from https://www.erc.or.th/th/electricity-service-rate

Exro. (2024, January). *Industry Insights: California's NEM 2.0 vs NEM 3.0: A Comprehensive Comparison.* Retrieved from Exro: https://www.exro.com/industry-insights/california-net-energy-metering-policies

Farooquee, A. A., & Shrimali, G. (2016, August). Making renewable energy competitive in India: Reducing financing costs via a government-sponsored hedging facility. *Energy Policy, 95*, 518-528.

Fields, S., & McDevitt, C. (2024, January 31). *Vehicle-to-grid charging: What you need to know*. Retrieved from Energysage: https://www.energysage.com/ev-charging/vehicle-to-grid-charging-what-you-need-to-know/

GSB. (2024, January). *GSB Go Green (in Thai)*. Retrieved from GSB: https://www.gsb.or.th/media/2024/01/Sale-Sheet-%E0%B8%AA%E0%B8%B4%E0%B8%99%E0%B9%80%E0%B8%8A%E0%B8%B7%E0%B9%88%E0%B8%AD%E0%B8%9A%E0%B8%B8%E0%B8%84%E0%B8%84%E0%B8%A5-GSB-Go-Green.pdf

Gujarat Government. (2023, December). *What is New: Ensuring Quality at Scale: Empowering Green Energy in Gujarat through Grid Connected Rooftop Solar.* Retrieved from National Portal: https://pmsg-production-public.s3.ap-south-1.amazonaws.com/notifications/162_notification.pdf

Gulia, J., Gupta, K., Sharma, P., & Garg, V. (2023). *The Rooftop Solar Commercial & Industrial Market in India.* Lakewood: Institute for Energy Economics and Financial Analysis. Retrieved from https://ieefa.org/sites/default/files/2023-08/IEEFA_JMK_Rooftop%20Solar%20Commercial%20and%20Industrial%20Market_August%202023.pdf

Gunarathna, C. L., Yang, R. J., Jayasuriya, S., & Wang, K. (2022). Reviewing global peer-to-peer distributed renewable energy trading projects. *Energy Research & Social Science*, 102655.

Gurufocus. (n.d.). *Thai Solar Energy PCL (BKK: TSE) WACC %*. Retrieved from https://www.gurufocus.com/term/wacc/BKK:TSE

Hawaiian Electric. (2024). *Oahu Locational Value Map (LVM).* Retrieved from https://www.hawaiianelectric.com/clean-energy-hawaii/integration-tools-and-resources/locational-value-maps/oahu-locational-value-map-(lvm)

Hawaiian Electric. (2024, April). *Products & Services: Smart Renewable Energy programmes*. Retrieved from Hawaiian Electric: https://www.hawaiianelectric.com/products-and-services/smart-renewable-energy-programmes

Hawaiian Electric. (n.d.-a). *Billing & Payment: Average Price of Electricity*. Retrieved from https://www.hawaiianelectric.com/billing-and-payment/rates-and-regulations/average-price-of-electricity

IEEE. (2023, August 28). *IEEE 1547-2018: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.* Retrieved from IEEE Standards Association: https://standards.ieee.org/ieee/1547/5915/

IREC. (2017, December). *Optimizing ghe Grid: A Regulator's Guide to Hosting Capacity Analyses for Distributed Energy Resources.* Albany: IREC US. Retrieved from https://irecusa.org/wp-content/uploads/2021/07/IREC-Optimizing-the-Grid-2017-1.pdf

IRENA. (2020). *Renewable Energy Finance: Green Bonds.* Abu Dhabi: IRENA. Retrieved from https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jan/IRENA_RE_finance_Green_bonds_2020.pdf

IRENA. (2023). *Renewable Power Generation Costs in 2022.* Interstate Renewable Energy Agency. Retrieved from https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022

Irfan, M., Deilami, S., Huang, S., & Veettil, B. P. (2023). Rooftop Solar and Electric Vehicle Integration for Smart, Sustainable Homes: A Comprehensive Review. *Energies*, 7248.

Junlakarn, S., Kokchang, P., & Audomvongseree, K. (2022). Drivers and Challenges of Peer-to-Peer Energy Trading Development in Thailand. *Energies*, 1229.

Kasikorn Bank. (2020, November). *Home Loan Refinanace (in Thai)*. Retrieved from Kasikorn Bank: https://www.kasikornbank.com/TH/personal/Loan/HomeLoan/Pages/HomeLoanRefinance.aspx

Kasikorn Bank. (2021, December). *The K–Energy Saving Guarantee programme for Solar Rooftop (in Thai)*. Retrieved from Kasikorn Bank: https://www.kasikornbank.com/TH/business/sme/loan/special-loan/pages/k-energy-saving-guarantee-programme-solar-rooftop.aspx

Kongphuthon, S. (2017). *Battery Knowledge Management: Excise Tax Act B.E. 2527 (1984) (in Thai).* Retrieved from The Excise Department: https://www.excise.go.th/cs/groups/%E0%B8%9E%E0%B8%B7%E0%B9%89%E0%B8%99%E0%B8%97%E0%B8%B5%E0%B9%88%E0%B8%AD%E0%B8%B8%E0%B8%95%E0%B8%A3%E0%B8%94%E0%B8%B4%E0%B8%95%E0%B8%96%E0%B9%8C/documents/document/mjaw/mdy4/~edisp/webportal16200068731.pdf

Krungsri Bank. (2022, May). *Solar Rooftop Loan (in Thai)*. Retrieved from Krungsri Bank: https://www.krungsri.com/th/business/loans/solar-rooftop

Krungthai Bank. (2022, October). *Solar Rooftop Loan to Support Energy Saving (in Thai)*. Retrieved from Krungthai Bank: https://krungthai.com/th/corporate/ktb-business-loan/163/539

Kulkarni, S. (2024, February 2). *Budget 2024: Save up to Rs 18000 a year in electricity bills via Pradhan Mantri Suryodaya Yojana rooftop solar power scheme; who is eligible.* Retrieved from The Economic Times: https://economictimes.indiatimes.com/wealth/save/budget-2024-pradhan-mantri-suryodaya-yojana-rooftop-solar-power-scheme-will-help-users-save-up-to-rs-18000-a-year-in-electricity-bills-who-is-eligible/articleshow/107315470.cms?from=mdr

Kumar, V. (2022, October 3). *Office Memoradum: Clarification on applicability of CFA available under Rooftop Solar (RTS) programme Phase-II for solar systems installed under Virtual Net Metering (VNM) arrangement.* Retrieved from S3WaaS – Secure, Scalable and Sugamya Website as a Service: https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/10/20231005417871126.pdf

Manager Online. (2021, December 16). *KBank Partners to Extend 1.1 Billion Baht Supporting the solar power generation and sales business (in Thai)*. Retrieved from Manager Online: https://mgronline.com/stockmarket/detail/9640000124453

MEA. (2023, October). *Different types of electricity tariffs (in Thai)*. Retrieved from MEA: https://www.mea.or.th/our-services/tariff-calculation/other

MEA. (2023, October). *Latest Ft Value (in Thai)*. Retrieved from MEA: https://www.mea.or.th/our-services/tariff-calculation/latestft

MNRE India. (2024, January). *Home: Grid Connected Solar Rooftop programme*. Retrieved from Ministry of New and Renewable Energy, India: https://mnre.gov.in/grid-connected-solar-rooftop-programme/

MNRE India. (2024, February). *National portal*. Retrieved from National portal : https://www.pmsuryaghar.gov.in/

National Informatics Centre. (2023, December). *What is New: National Portal for Rooftop Solar.* Retrieved from National Portal: https://pmsg-production-public.s3.ap-south-1.amazonaws.com/notifications/166_notification.pdf

Next Kraftwerke. (2024, February 28). *What is a Power Purchase Agreement (PPA)?* Retrieved June 4, 2024, from Next Kraftwerke: https://www.next-kraftwerke.be/knowledge-hub/ppa-power-purchase-agreement#sleeved-ppa

Nhede, N. (2019, November 12). Thailand's First certified climate bond. Retrieved from Smart Energy International: https://www.smart-energy.com/policy-regulation/thailands-first-certified-climate-bonds/

Novergy Energy Solutions. (2024, March 26). Exploring The 8 Different Types Of Power Purchase Agreements (PPAs). Retrieved from Novergy: Power Generation for Generations: https://www.novergysolar.com/types-power-purchase-agreements-ppa-and-which-one-best-for-you/

OECD. (2024, March 26). Clean Energy Finance and Investment Roadmap of Thailand, Green Finance and Investment. Paris: OECD Publishing. Retrieved from https://www.oecd-ilibrary.org/environment/clean-energy-finance-and-investment-roadmap-of-thailand_ea8fd683-en

ONEP. (2022). Thailand's Long-Term Low Greenhouse Gas Emission Development Strategy (Revised version). Bangkok: Office of Natural Resources and Environmental Policy and Planning, Ministry of Natural Resources and Environment. Retrieved from https://unfccc.int/sites/default/files/resource/Thailand%20LT-LEDS%20%28Revised%20Version%29_08Nov2022.pdf

Potisat, T., Kuvarakul, T., Yaowapruek, B., & Moungcharoen, S. (2017). Renewable energy guidelines on solar PV rooftop implementation: Thailand. Bangkok: GIZ and USAID Clean Power Asia. Retrieved from https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID-Clean-Power-Asia_RE-Guidelines-Solar-PV-Rooftop-Implementation-EN-v1.pdf

Prachachat Online. (2024, January 13). "Solar Rooftop Installation Could Bring Up to 200,000 Baht in Tax Deductions, Boosting Thai Households' Adoption to 90,000 Per Year (in Thai). Retrieved from Prachachat Online: https://www.prachachat.net/economy/news-1478839

Praiwan, Y. (2024, May 17). Solar rooftop adopters set to win a tax break. Retrieved from Bangkok Post: https://www.bangkokpost.com/business/general/2794574/solar-rooftop-adopters-set-to-win-a-tax-break

SCB. (2021, May). SCB SME Go Green (in Thai). Retrieved from SCB: https://www.scb.co.th/th/sme-banking/total-solutions/campaign-solution/sme-go-green.html

Smith, K. M., Koski, C., & Siddiki, S. (2021, March). Regulating net metering in the United States: A landscape overview of states' net metering policies and outcomes. The Electricity Journal, 34(2), 106901. Retrieved from https://www.sciencedirect.com/science/article/pii/S1040619020301937

Solaroo. (2021, December 1). Solaroo Partners Allianz General For Residential Solar PV Insurance. Retrieved from Solaroo: https://solaroo.com/allianzsolaroopartner/

TDRI. (2019, September 3). Suitability and Guidelines for Promoting the Energy Storage Battery Industry in Thailand's Electricity Grid (in Thai). Bangkok: TDRI. Retrieved from https://tdri.or.th/wp-content/uploads/2019/09/Seminar-phase-II-ALL-FINAL-@8am-1.pdf

TGO. (2016, June 16). WHAT IS T-VER? (in Thai). Retrieved June 4, 2024, from Thailand Greenhouse Gas Mitigation Mechanism : https://ghgreduction.tgo.or.th/en/what-is-t-ver/what-is-t-ver.html

ThaiBMA. (2018, November 7). *Bond Blogs*. Retrieved from ThaiBMA: https://www.thaibma.or.th/EN/Investors/Individual/Blog/2018/07112018.aspx#:~:text=%E0%B9%83%E0%B8%99%E0%B9%80%E0%B8%94%E0%B8%B7%E0%B8%AD%E0%B8%99%E0%B8%81%E0%B8%B1%E0%B8%99%E0%B8%A2%E0%B8%B2%E0%B8%A2%E0%B8%99%202561%20%E0%B8%97%E0%B8%B5%E0%B9%88,%E0%B8%AB

The Nation. (2024, March 11). *KBank, INNOPOWER to launch Renewable Energy Certificate platform (in Thai)*. Retrieved June 4, 2024, from The Nation: https://www.nationthailand.com/blogs/business/banking-finance/40036295

Tongsopit, S., Junlakarn, S., Chaianong, A., Overland, I., & Vakulchuk, R. (2024, January 30). Prosumer solar power and energy storage forecasting in countries with limited data: The case of Thailand. *Heliyon, 10*(2). Retrieved from https://www.sciencedirect.com/science/article/pii/S2405844024000288

Tongsopit, S., Junlakarn, S., Wibulpolprasert, W., Chaianong, A., Kokchang, P., & Hoang, N. V. (2019). The economics of solar PV self-consumption in Thailand. *Renewable Energy*, 395-408.

Tongsopit, S., Moungchareon, S., Aksornkij, A., & Potisat, T. (2016). Business models and financing options for a rapid scale-up of rooftop solar power systems in Thailand. *Energy Policy*, 447-457.

TTB Bank. (2023, May). *TTB solar rooftop solution (in Thai)*. Retrieved from TTB Bank: https://www.ttbbank.com/th/corporate/corp-sustainable-and-sufficient-funding/corp-fwb-long-term-loan/corp-ttb-solar-rooftop-solution

UOB. (2021, July). *U-Solar (in Thai)*. Retrieved from UOB Group: https://www.uobgroup.com/u-solar-th/index.page#viewsolarpackages

Veilleux, G., Potisat, T., Pezim, D., Ribbback, C., Ling, J., Krysztofinski, A., . . . Chucherd, S. (2020, February). Techno-economic analysis of microgrid projects for rural electrification: A systematic approach to the redesign of Koh Jik off-grid case study. *Energy for Sustainable Development, 54*, 1-13. Retrieved from https://www.sciencedirect.com/https://www.sciencedirect.com/science/article/pii/S0165188921001366

World Bank. (2022, June 28). *World Bank Provides $165 Million to Support Renewable Energy in India's Residential Sector*. Retrieved from World Bank: https://www.worldbank.org/en/news/press-release/2022/06/28/world-bank-provides-165-million-to-support-renewable-energy-in-india-s-residential-sector

Annex 1: Methodology

This study employed both qualitative and quantitative analysis, including a desk review and semi-structured interviews of eight stakeholders (4 from the private sector, 3 from public sector and 1 from financial institutions) during December 2022 to February 2023. The interview sessions were structured around two primary components: (1) an overview of the interviewees' enterprises and climate-related services and (2) their perspectives on success factors, risks, and expectations of rooftop solar investment in Thailand. These risks underwent verification through a focus group meeting involving relevant stakeholders.

The quantitative part of the study adopted the methodology set out in the **UNDP's De-risking Renewable Energy Investment (DREI) framework** to quantify the impact of risk categories on the financial costs (so called risk waterfall analysis). Following the DREI framework, data for modelling (including cost of equity, cost of debt and capital structure, etc.) were collected through survey responses obtained from 13 participants from the private sector and financial institutions. The analysis was conducted as follows:

Stage 1: Identify the main risk categories and their underlying barriers based on data and information collected through the survey and focus groups.

Stage 2: Estimate risk premiums for the cost of equity and cost of debt based on the differences between the 'best-case' and the 'business as usual or BAU case'. We identify the 'best-case' scenario for cost of equity and cost of debt based on a selective comparable company in Thailand engaging in the generation and distribution of electricity from solar power to the government and private sector (e.g. Thai Solar Energy PCL (Gurufocus, n.d.)). This best-case scenario represents the best comparative cost of equity (7.3%) and cost of debt (2.4% on average) of the same business operating in Thailand. We also identify 'business as usual or BAU' scenario for cost of equity (11.5% on average) and cost of debt (5.3% on average) based on the analysis of current financial cost data for rooftop solar projects collected through the survey. Then, risk premiums were estimated for both cost of equity and cost of debt based on the difference between the 'best-case' and 'BAU' scenarios.

Stage 3: Calculate the impact of risk categories on the cost of equity and cost of debt in Thailand. In the survey, the participants were asked to rate the probability of each particular risk category occurring from 1 (unlikely) to 5 (very likely) and the financial impact of each risk category from 1 (low impact) to 5 (high impact). We calculated the total risk scores by multiplying the probability and impact of each risk category. Then, we prorate risk scores across the estimated risk premiums for cost of equity and cost of debt, respectively, illustrating this through risk waterfall analysis.

Annex 2: LCOE assumptions

Table A2-1 Price assumptions for finding LCOE values

	Unit	Residential	Commercial	Industrial	Sources
System size	kW	5	107	514	Determined by authors
System costs (module, inverter, balance of system equipment, labour installation, installer and developer margin and sale tax)	THB/W	34.10	27.81	23.66	Authors complied (e.g. Thailand solar working group, price survey, interview)
Operation and Maintenance cost	THB/year	5,900	13,430	39,100	Authors complied (e.g. studies and interview)
Battery size	kWh	9.6	99.3	499.6	Battery size based on electricity generated from PV system size
Battery cost	THB/kWh	22,968.75	17,379.78	15,447.08	Price from online source with excise tax https://www.excise.go.th/cs/groups/พื้นที่อุตรดิตถ์/documents/document/mjaw/mdy4/~edisp/webportal16200068731.pdf

	Unit	Residential	Commercial	Industrial	Sources
Analysis period	Year	25	25	25	Determined by the warranty of solar module
Loan term	Year	5	5	9	www.emenergy.co.th/ สินเชื่อโซล่ารูฟท็อป
Loan rate	%/year	7.02	7.02	7.02	www.emenergy.co.th/ สินเชื่อโซล่ารูฟท็อป
Sales tax	%	9.33	9.33	9.33	Based on EPC price survey (0% from year 1-8 and 20% from year 9-15)
Inflation rate	%	2.5	2.5	2.5	(Tongsopit, et al., 2019)
Real discount rate/ WACC for loan 0%	%	11.5	11.5	11.5	Based on the cost of debt and cost of equity from the survey
Real discount rate/ WACC for loan 70%	%	7.16	7.16	7.16	Based on the cost of debt and cost of equity from the survey
Electricity tariff					
TOU (including Ft and Vat)	THB/kWh	Peak: 6.195 Off-peak: 3.034	Peak: 4.581 Off-peak: 3.000	Peak: 4.581 Off-peak: 3.000	FT from May-Aug 2024 https://www.mea.or.th/our-services/tariff-calculation/other
Service charge	THB/month	24.62	312.24	312.24	https://www.mea.or.th/our-services/tariff-calculation/other
Electricity bill escalation rate	%/year	1.6	1.6	1.6	-

CASE
for Southeast Asia