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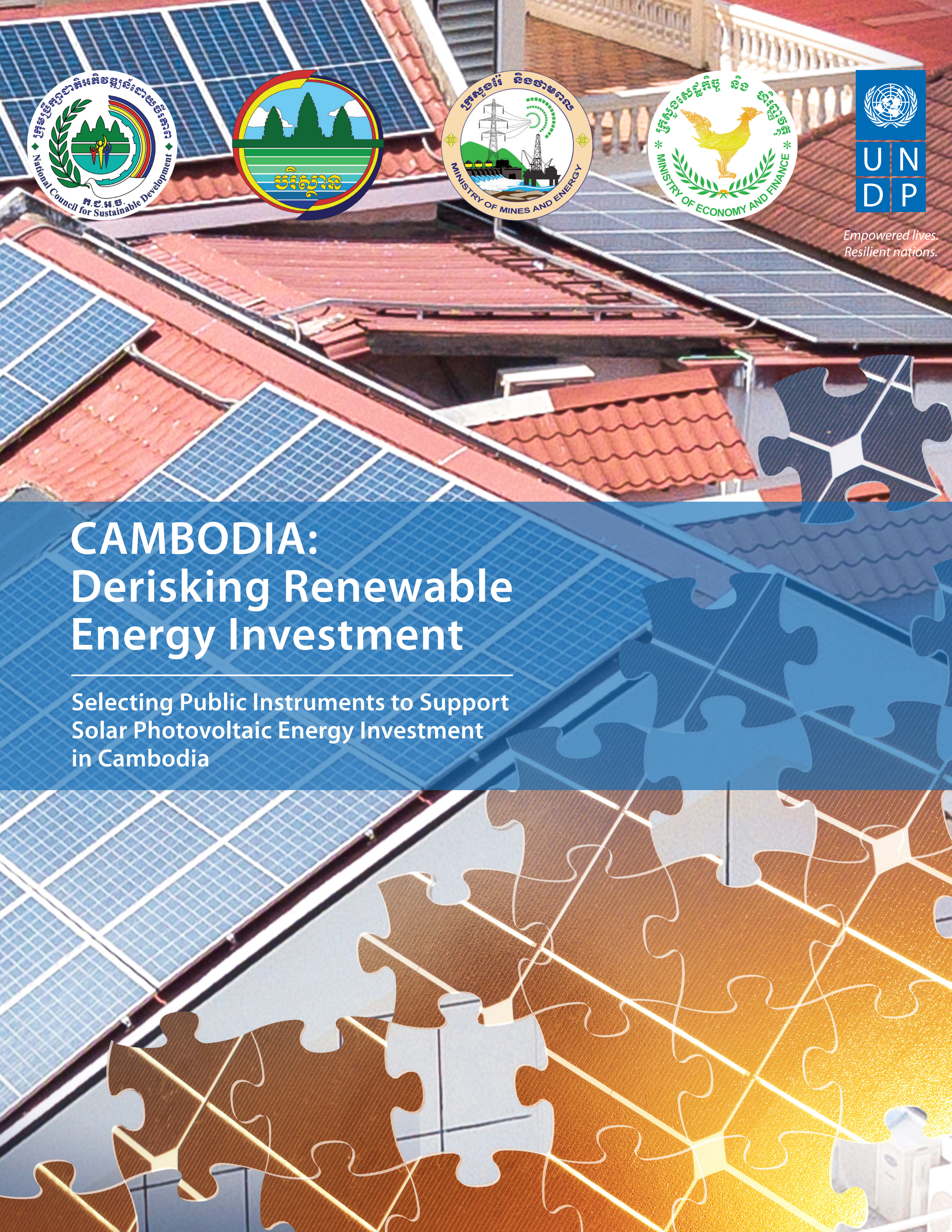

National Council for Sustainable Development

Ministry of Mines and Energy

Ministry of Economy and Finance

UNDP

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CAMBODIA: Derisking Renewable Energy Investment

Selecting Public Instruments to Support Solar Photovoltaic Energy Investment in Cambodia

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This publication builds on a series of prior research papers. This includes the original *Derisking Renewable Energy Markets* (UNDP, 2013) report, which sets out the methodology used in this publication.

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Table of Contents

Figures, Tables and Boxes

Figures, Tables and Boxes

Figures

TABLES

BOXES

Acronyms

ADB	Asian Development Bank
AFD	Agence Française de Développement
BAU	Business-as-usual
BOS	Balance of system
CCGT	Combined cycle gas turbine
CoD	Cost of debt
CoE	Cost of equity
CO_2e	Carbon dioxide equivalent
C&I	Commercial and industrial
DREI	Derisking renewable energy investment
EAC	Electricity Authority of Cambodia
EDC	Electricité Du Cambodge
EIU	Economist Intelligence Unit
EPC	Engineering, procurement and construction
EU	European Union
FiT	Feed-in-tariff
GDE	General Department of Energy (of MME)
GEF	Global Environment Facility
GGGI	Global Green Growth Institute
GPP	Global Purify Power
GWh	Gigawatt hour
hh	Household
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IPP	Independent power producer
IRENA	International Renewable Energy Agency
KfW	German Development Bank

kW	Kilowatt
kWh	Kilowatt-hour
kWp	Kilowatt-peak
LCOE	Levelized Cost Of Electricity
m	million
MG	Mini-grid
MME	Ministry of Mines and Energy
MW	Megawatt
MRV	Measuring, reporting and verification
MW	Megawatt
MWh	Megawatt-hour
MWp	Megawatt-peak
mt	Million tonnes
N/A	Not applicable
NDC	Nationally Determined Contribution
NCSD	National Council for Sustainable Development
NREL	National Renewable Energy Laboratory
OECD	Organisation of Economic Co-Operation and Development
O&M	Operation & maintenance
PAYG	Pay-as-you-go
PEC	Provincial Electricity Company
PPA	Power purchase agreement
PV	Photovoltaic
RE	Renewable Energy
REE	Rural Electricity Enterprise
REF	Rural Electrification Fund
SEAC	Solar Energy Association Cambodia
SHS	Solar Home System
SNV	Netherland Development Organisation
SREP	Scaling-up Renewable Energy Program
SRET	Scaling-up Renewable Energy Technologies
UNDP	United Nations Development Programme

UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
VAT	Value-added tax
VRE	Variable renewable energy
WACC	Weighted average cost of capital
WB	World Bank
Wp	Watt peak
WRI	World Resources Institute
WWF	World Wildwilfe Fund
3i	Investing in Infrastructure

Foreword

Foreword

For nearly two decades, the National Strategic Development Plan, now guided by Rectangular Strategy Phase IV (RS4), has committed to enhancing Cambodia's robust levels of socio-economic development. Each of the national plans and strategies give significant attention to a well-developed electricity sector as an essential component towards unlocking future growth and prosperity.

In this regard, the Royal Government of Cambodia (RGC) continues to lower electricity costs to consumers and reduce reliance on power imports, while expanding access to grid-quality electricity in rural and remote communities. Cambodia has achieved outstanding progress towards providing electricity access for all, nearly meeting its electrification targets and building a strong foundation to transform the economy.

Cambodia has strong potential for solar energy, in fact some of the most robust levels of solar irradiation that can provide the country an opportunity to meet growing electricity demands in an economical, innovative and sustainable way. The RGC seeks to best realize this potential and operationalize the goals set out by the RS4. The RS4 emphasizes increased investments in clean and renewable energy, especially solar power, to limit generation from unclean sources, lower-carbon emissions and ensure long-term energy security for Cambodia.

One way to encourage and support investments in clean and renewable energy is by derisking them and creating a favourable and enabling environment for investors in this sector. Cambodia's Derisking Renewable Energy Investment (DREI) report does this with a focus on solar energy across four sub-sectors; utility scale solar, rooftop PV solar, solar battery mini-grids and solar home systems. In this regard, Cambodia's DREI report has sought to adapt innovative solar power policies and financing solutions to the national context and craft a fully localised set of – cost-effective derisking measures – which serve as an input to national and sectoral energy development planning processes and help shape the forthcoming update to the Power Development Plan.

Cambodia has already piloted two large-scale solar farm projects in the country. As new opportunities for renewable electricity generation continue to emerge as affordable options to power the country, the RGC will continue to seek necessary reforms in order to harness the potential benefits for all Cambodians. The National Council for Sustainable Development is thankful for the contributions received for this report, from ministries and all other stakeholders, including UNDP, private sector investors, civil society organizations, and development partners.

Phnom Penh 21 May 2019

Say Samal
Chair of the National Council for Sustainable Development
Minister of Environment

Key Points for Decision Makers

ចំណុចសំខាន់ៗសម្រាប់អ្នករៀបចំគោលនយោបាយ[១]

ហេតុអ្វីកម្ពុជាត្រូវការថាមពលពន្លឺព្រះអាទិត្យ?

- **ប្រទេសកម្ពុជាមានសក្តានុពលខ្ពស់ក្នុងការផលិតថាមពលពីពន្លឺព្រះអាទិត្យ(PV)៖** នៅប្រទេសកម្ពុជា តម្រូវការថាមពលអគ្គិសនីកំពុងមានការកើនឡើងយ៉ាងឆាប់រហ័ស ដូច្នេះថាមពលពន្លឺព្រះអាទិត្យអាចជួយបំពេញបន្ថែមកំណើនតម្រូវការនេះ និងអាចជួយបង្កើនសន្តិសុខថាមពលប្រកបដោយចីរភាព។ ថាមពលនេះក៏ជួយលើកកម្ពស់កម្រិតអគ្គិសនីភាវូបនីយកម្មតាមរយៈបច្ចេកវិទ្យាដែលមិនភ្ជាប់នឹងបណ្តាញរដ្ឋ(off-grid) និងគំរូអាជីវកម្មដែលមានភាពច្នៃប្រឌិត។ ប្រទេសកម្ពុជាក៏អាចប្រើថាមពលនេះដើម្បីរួមចំណែកឆ្លើយតបនឹងការប្រែប្រួលអាកាសធាតុក្រោមកិច្ចព្រមព្រៀងអាកាសធាតុរបស់អង្គការសហប្រជាជាតិផងដែរ។

គោលដៅនៃរបាយការណ៍នេះ

- **កំណត់វិធានការកាត់បន្ថយហានិភ័យដែលមានប្រសិទ្ធភាពចំណាយ៖** របាយការណ៍នេះមានគោលបំណងធ្វើការវិភាគលើវិធានការសាធារណៈដែលមានប្រសិទ្ធភាពចំណាយបំផុត ដើម្បីគាំទ្រការវិនិយោគរបស់វិស័យឯកជនលើផ្នែកថាមពលពន្លឺព្រះអាទិត្យនៅកម្ពុជា។ របាយការណ៍នេះបានសិក្សាទិន្នន័យ និងហានិភ័យផ្សេងៗក្នុងវិស័យឯកជននេះយ៉ាងល្អិតល្អន់។ របាយការណ៍នេះបានផ្សព្វផ្សាយជាសាធារណៈនូវគ្រប់ម៉ូដែលហិរញ្ញវត្ថុ ទិន្នន័យ និងតម្លៃសន្មតនានា ដែលបានប្រើប្រាស់។

- **ការវិភាគលើអនុវិស័យទាំងបួន៖** ដោយប្រើវិធីសាស្រ្តបែបទូលំទូលាយ របាយការណ៍នេះផ្តោតលើអនុវិស័យថាមពលពន្លឺព្រះអាទិត្យចំនួនបួនផ្សេងគ្នា គឺ៖
    - **ប្រព័ន្ធតភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ (on-grid)** ដែលរួមមាន៖ ១.ថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនី (utility-scale photovoltaics) និង ២. ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ (roof-top photovoltaics)
    - **ប្រព័ន្ធមិនភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ (off-grid)** ដែលរួមមាន៖ ៣. បណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើប្រាស់ថាមពលពន្លឺព្រះអាទិត្យនិងអាគុយ (solar-battery mini-grids) និង ៤. ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះ (solar home system)

- **ចំណុចដៅវិនិយោគដោយផ្នែកឯកជន៖** ចំពោះអនុវិស័យនិមួយៗខាងលើ របាយការណ៍នេះបានកំណត់ចំណុចដៅសន្មតសម្រាប់ការវិនិយោគដោយផ្នែកឯកជនដូចខាងក្រោម៖

[១] "ចំណុចគន្លឹះសម្រាប់អ្នករៀបចំគោលនយោបាយ" សង្ខេបលទ្ធផលរកឃើញនៃរបាយការណ៍នេះដោយខ្លីបំផុត។ ដូច្នេះឯកសារយោងនានាពុំត្រូវបានបញ្ចូលក្នុងផ្នែកនេះឡើយ ប៉ុន្តែអាចរកបានក្នុងផ្នែកនានានៃរបាយការណ៍ទាំងមូល។

- **ប្រព័ន្ធភ្ជាប់ជាមួយនឹងបណ្តាញអគ្គិសនីរដ្ឋ៖** ចំពោះថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនី ការសិក្សាសន្មតយកចំណុចដៅចំនួន៣៥០មេហ្គាវ៉ាត់ (MW) និង៣៥០មេហ្គាវ៉ាត់ (MW) ទៀតសម្រាប់ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ ត្រឹមឆ្នាំ២០៣០។ ជាសរុប ចំណុចដៅនៃអនុវិស័យទាំងពីរមានអានុភាពសរុប ៧០០មេហ្គាវ៉ាត់ (MW)[២] ដែលស្មើនឹង២០%នៃសមត្ថភាពផ្គត់ផ្គង់អគ្គិសនីសរុបនៅឆ្នាំ២០៣០។
- **ប្រព័ន្ធដែលមិនភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ៖** ចំពោះបណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើប្រាស់ថាមពលពន្លឺព្រះអាទិត្យនិងអាគុយ និងប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះដែលបង់ថ្លៃតាមរបៀប pay-as-you-go (PAYG) ចំណុចដៅនៃអនុវិស័យនេះត្រូវបានសន្មតដោយចាប់ផ្តើមធ្វើជាជំហាន/ដំណាក់កាលចំនួន១០មេហ្គាវ៉ាត់(MW) ត្រឹមឆ្នាំ២០២៥។ គេអាចធ្វើជាដំណាក់កាលរបៀបនេះពី៤ទៅ៦ដងដើម្បីបំពេញចំនុចដៅសន្មត(១០ MWនេះ) សម្រាប់អនុវិស័យនិមួយៗ។

ការរកឃើញសំខាន់ៗ

- **ឱកាសវិនិយោគច្រើនជាង៩០០លានដុល្លារអាមេរិកក្នុងវិស័យថាមពលពន្លឺព្រះអាទិត្យ៖** ប្រទេសកម្ពុជាមានសក្តានុពលទាក់ទាញការវិនិយោគឯកជនយ៉ាងខ្លាំង ក្នុងទំហំវិនិយោគសរុបប្រមាណ៩០៣លានដុល្លារអាមេរិកពីអនុវិស័យទាំងបួន។
- **ការផលិតអគ្គិសនីពីថាមពលពន្លឺព្រះអាទិត្យមានតម្លៃទាបជាងមុន៖** បច្ចេកវិទ្យាក្នុងអនុវិស័យថាមពលពន្លឺព្រះអាទិត្យទាំងបួនមានតម្លៃកាន់តែទាក់ទាញសម្រាប់ទីផ្សារបច្ចុប្បន្ន ហើយវានឹងផ្តល់នូវអគ្គិសនីក្នុងតម្លៃទាបជាងការផលិតពីធ្យូងថ្មនិងវារីអគ្គិសនី នៅពេលដែលហានិភ័យវិនិយោគក្នុងវិស័យនេះត្រូវបានកាត់បន្ថយ។
- **ការកាត់បន្ថយហានិភ័យវិនិយោគនឹងផ្តល់នូវអត្ថប្រយោជន៍ជាក់ស្តែងដល់ប្រទេសកម្ពុជា៖** របាយការណ៍នេះបានស្នើនូវសំណុំវិធានការសាធារណៈបែបទូលំទូលាយនិងជាប្រព័ន្ធ ដោយពិនិត្យមើលអំពីហានិភ័យវិនិយោគ ក្នុងអនុវិស័យថាមពលពន្លឺព្រះអាទិត្យទាំងនេះ។ ការវិភាគនេះបានរកឃើញអត្ថប្រយោជន៍ជាច្រើនរួមមាន៖ **កំណើនការវិនិយោគ ការសន្សំសំចៃផ្នែកសេដ្ឋកិច្ច ការសម្រួលលទ្ធភាពជាវសេវាអគ្គិសនី ការទទួលបានអគ្គិសនីនិងកាត់បន្ថយឧស្ម័នផ្ទះកញ្ចក់។** លទ្ធផលម៉ូដែលបង្ហាញថា ការអនុវត្តវិធានការកាត់បន្ថយហានិភ័យសម្រាប់អនុវិស័យទាំងបួន (ដូចដែលលំអិតក្នុងរបាយការណ៍ខាងក្រោម) នឹងផ្តល់នូវប្រសិទ្ធភាពខ្ពស់និងចំណាយតិច។

[២] ចំណុចដៅដែលមានអានុភាព៣៥០MW សម្រាប់ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ និង៣៥០MW សម្រាប់ថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្ម អគ្គិសនី (ជាសរុបគឺ៧០០MW) មិនមែនជាចំណុចដៅផ្លូវការដែលកំណត់ដោយរដ្ឋាភិបាលកម្ពុជាទេ។ វាជាតម្លៃសន្មតរបស់អ្នកនិពន្ធផ្អែកលើបទពិសោធន៍របស់ អន្តរជាតិ និងបានឆ្លងការប្រឹក្សាយោបល់ពីភ្នាក់ងាររដ្ឋាភិបាល និងភាគីពាក់ព័ន្ធ។ ម្យ៉ាងទៀត ចំណុចដៅនេះមិនមែនបានន័យថាបណ្តាញអគ្គិសនីរដ្ឋមាន សមត្ថភាពបច្ចេកទេសទទួលបានតែ៧០០MW ពីប្រភពថាមពលកកើតឡើងវិញនោះទេ។ ចំណុចដៅនេះជាតម្លៃសន្មតដើម្បីយកទៅប្រើប្រាស់ក្នុងការធ្វើម៉ូដែល ហិរញ្ញវត្ថុ និងសេដ្ឋកិច្ច ដោយសង្ឃឹមទុកថាបណ្តាញអគ្គិសនីរដ្ឋនឹងបន្តអភិវឌ្ឍទៅមុខបន្តទៀត ដើម្បីអាចទទួលយកប្រភពថាមពលកកើតឡើងវិញបានកាន់តែច្រើន ដោយគ្មានការរំខានដល់ស្ថិរភាពបណ្តាញអគ្គិសនី។ ផែនការអភិវឌ្ឍន៍អគ្គិសនីថ្មីដែលត្រូវរៀបចំនៅឆ្នាំ២០១៩ នឹងកំណត់ពីបរិមាណនៃប្រភពថាមពលកកើតឡើងវិញដែលភ្ជាប់ទៅនឹងបណ្តាញអគ្គិសនីរដ្ឋ។

ការអនុវត្តវិធានការ ដែលបានស្នើឡើង នឹងផ្តល់ផលចំនេញសេដ្ឋកិច្ចរហូតដល់១៤៦លានដុល្លារ[៣]។ តារាងទី១ ខាងក្រោមនេះផ្តល់ព័ត៌មានលំអិតជូនអ្នករៀបចំគោលនយោបាយអំពីកំណើនការវិនិយោគ និងផលចំណេញផ្នែកសេដ្ឋកិច្ចពីអនុវិស័យនិមួយៗ។ ឧទាហរណ៍៖ ចំពោះប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនីដែលតភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ របាយការណ៍នេះរកឃើញវិធានការសាធារណៈកាត់បន្ថយហានិភ័យចំនួន២០ ដែលនឹងចំណាយ ប្រហែល៣៩លានដុល្លារអាមេរិក ប៉ុន្តែអាចផ្តល់ការទាក់ទាញគម្រោងវិនិយោគជាង២៨០លានដុល្លារអាមេរិកពី វិស័យឯកជន និងមានការចំណេញសេដ្ឋកិច្ចសរុបចំនួន៦០លានដុល្លារ ត្រឹមឆ្នាំ២០៣០។

តារាងទី១៖ ការវិនិយោគ និងផលចំណេញពីការអនុវត្តសំណុំវិធានការកាត់បន្ថយហានិភ័យវិនិយោគថាមពលពន្លឺព្រះអាទិត្យនៅកម្ពុជា សម្រាប់អនុវិស័យទាំងបួន (លានដុល្លាអាមេរិច)

ប៉ារ៉ាម៉ែត្រ	ប្រព័ន្ធតភ្ជាប់នឹងបណ្តាញរដ្ឋ		ប្រព័ន្ធមិនតភ្ជាប់នឹងបណ្តាញរដ្ឋ	
	ថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនី	ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ[៤]	បណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើប្រាស់ថាមពលពន្លឺព្រះអាទិត្យនិងអាគុយ	ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះ
ការវិនិយោគរបស់វិស័យឯកជន	២៨០	៣៣៩	៣៥	១២
ផលចំណេញសេដ្ឋកិច្ចពីការអនុវត្តវិធានការកាត់បន្ថយហានិភ័យ	៦០	៦១	១៨	៧
ចំណាយសាធារណៈលើការកាត់បន្ថយហានិភ័យ	៣៩	១៦	១០	៣
អនុសាសន៍សម្រាប់កាត់បន្ថយ ហានិភ័យ	វិធានការចំនួន២០ (ក្នុងនោះមានផ្នែកគោលនយោបាយចំនួន ១៧ និងផ្នែក ហិរញ្ញវត្ថុចំនួន៣)	វិធានការចំនួន១៨(ក្នុងនោះមានផ្នែកគោលនយោបាយចំនួន១៧ និងផ្នែក ហិរញ្ញវត្ថុចំនួន១និងផ្នែកហិរញ្ញវត្ថុចំនួន១)	វិធានការចំនួន១៨ (ក្នុងនោះមានផ្នែកគោលនយោបាយចំនួន១៥ និងផ្នែក ហិរញ្ញវត្ថុចំនួន៣)	វិធានការចំនួន១៧ (ក្នុងនោះមានផ្នែកគោលនយោបាយចំនួន១៥ និងផ្នែក ហិរញ្ញវត្ថុចំនួន២)

- **វិធានការកាត់បន្ថយហានិភ័យដែលជាអាទិភាព៖ របាយការណ៏នេះរកឃើញវិធានការកាត់បន្ថយហានិភ័យជាអាទិភាព សម្រាប់អនុវិស័យនីមួយៗ ដោយផ្អែកតាមយោបល់ត្រលប់ (បែបគុណវិស័យ) ពីអ្នកវិនិយោគ (សូមមើលតារាងទី២)។ អ្នកវិនិយោគទទួលស្គាល់ថា វិធានការទាំងនេះមានសារៈសំខាន់ណាស់ក្នុងការទាក់ទាញគម្រោងវិនិយោគទ្រង់ទ្រាយធំដោយចំណាយទុនវិនិយោគទាប។**

[៣] ផលចំណេញសេដ្ឋកិច្ចប្រាប់ពីតំលៃផលចំណេញសរុបក្នុងពេលបច្ចុប្បន្នដែលបានទូទាត់រួច ដោយសារថ្លៃផលិតថាមពលមានតម្លៃថោកជាងមុន ដែលជាលទ្ធផលនៃការកាត់បន្ថយហានិភ័យអំឡុងអាយុកាលរបស់ទ្រព្យសកម្មនៃប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យ

[៤] គោលដៅវិនិយោគជារួមសម្រាប់ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារចំនួន៣៥០MW បែងចែកជាពីរ គឺ១៧៥MW សម្រាប់វិស័យពាណិជ្ជកម្ម និងឧស្សាហកម្ម (C&I) និង១៧៥ សម្រាប់វិស័យគេហដ្ឋាន។ លើកលែងតែតួលេខចំណាយវិនិយោគមូលធនសរុប ការវិភាគម៉ូដែលដែលប្រើប្រាស់ក្នុងរបាយការណ៍នេះ គឺធ្វើឡើងសម្រាប់តែថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារសម្រាប់វិស័យពាណិជ្ជកម្ម និងឧស្សាហកម្មតែប៉ុណ្ណោះ និងពុំបានលើកឡើងពីវិស័យ គេហដ្ឋាននោះឡើយ។

តារាងទី២៖ វិធានការកាត់បន្ថយហានិភ័យជាអាទិភាព (ដោយផ្អែកតាមយោបល់ត្រលប់ពីអ្នកវិនិយោគ) សម្រាប់អនុវិស័យថាមពលពន្លឺព្រះអាទិត្យទាំងបួននៅប្រទេសកម្ពុជា

អនុវិស័យថាមពលពន្លឺព្រះអាទិត្យ	វិធានការកាត់បន្ថយហានិភ័យជាអាទិភាព
ថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនី	• អនុវត្តយន្តការដេញថ្លៃដែលមានតម្លាភាព និងប្រកួតប្រជែង ដោយប្រើកិច្ចព្រមព្រៀងគំរូសម្រាប់ទិញលក់ថាមពល (standardized power purchase agreement)[៥] • ធ្វើការសិក្សាពីស្ថិរភាពបណ្តាញអគ្គិសនី និងចែករំលែកលទ្ធផលរកឃើញប្រកបដោយតម្លាភាព ព្រមទាំងផ្តល់ការគាំទ្រផ្នែកបច្ចេកទេសនិងសូហ្វវែរ(software) សម្រាប់ការគ្រប់គ្រងបណ្តាញអគ្គិសនី
ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ	• ពង្រីកបទបញ្ញត្តិដើម្បីគ្របដណ្តប់លើអតិថិជនដែលបានភ្ជាប់បណ្តាញតង់ស្យុងទាបព្រមទាំងកែសម្រួលការគិតថ្លៃអានុភាពប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យ[៦] • គោលនយោបាយដែលអនុញ្ញាតឱ្យនាំចេញអគ្គិសនីទៅបណ្តាញរដ្ឋ ឧទាហរណ៍តាមរយៈយន្តការវាស់ស្ទង់លើបរិមាណប្រើប្រាស់ជាក់ស្តែង(Net-metering) ឬបញ្ជីថ្លៃលក់បន្ថែម (Feed-in Tariff)
បណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើប្រាស់ថាមពលពន្លឺព្រះអាទិត្យ និងអាគុយ	• ពង្រឹងសមត្ថភាពស្ថាប័នរដ្ឋាភិបាលដែលមានស្រាប់ ឬបង្កើតស្ថាប័ន/អង្គភាពថ្មី ដើម្បីលើកកម្ពស់/ ត្រួតពិនិត្យ ឬជម្រុញអគ្គិសនីភាវូបនីយកម្មដែលមិនភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ • អនុវត្តរបបនិយ័តកម្មទ្វេ (ដែលរួមមានបែបទូលំទូលាយ និងការផ្តោតតែលើចំនុចអាទិភាព) រួមទាំងការផ្តល់អាជ្ញាបណ្ណផងដែរ • ពង្រីកវិសាលភាពគោលនយោបាយបច្ចុប្បន្នស្តីពីឌីជីថលភាវូបនីយកម្ម រួមនិងការពង្រីកសេវាទូរស័ព្ទគ្របដណ្តប់នៅជនបទអោយកាន់តែល្អ និងបង្កើនភាពប្រកួតប្រជែងផ្នែកសេវាផ្ទេរប្រាក់តាមទូរស័ព្ទចល័ត
ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះ	• អភិវឌ្ឍ និងអនុវត្តស្តង់ដារបច្ចេកវិទ្យាសម្រាប់សម្ភារៈដែលប្រើប្រាស់ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះ • ពង្រីកវិសាលភាពគោលនយោបាយបច្ចុប្បន្នស្តីពីឌីជីថលភាវូបនីយកម្ម រួមនឹងការពង្រីកសេវាគ្របដណ្តប់សេវាទូរស័ព្ទនៅជនបទអោយកាន់តែល្អ និងបង្កើនភាពប្រកួតប្រជែងសេវាផ្ទេរប្រាក់ដោយទូរស័ព្ទចល័ត

- **ពង្រឹងតម្លាភាព និងធ្វើអោយប្រសើរឡើងមុននូវបទបញ្ញត្តិដែលអាចជម្រុញការវិនិយោគប្រព័ន្ធដែលតភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ៖** សម្រាប់ការតភ្ជាប់ជាមួយនឹងបណ្តាញរដ្ឋ ថាមពលពន្លឺព្រះអាទិត្យអាចជួយកម្ពុជាក្នុងការបំពេញតម្រូវការថាមពលដែលកំពុងមានការកើនឡើង និងលើកកម្ពស់សន្តិសុខថាមពលរបស់ខ្លួនព្រមទាំងអាចបន្ថយការនាំចូលអគ្គិសនីនៅរដូវប្រាំងផងដែរ។ តាមរយៈគោលនយោបាយ និងការវិនិយោគផ្នែកថាមពលពន្លឺព្រះអាទិត្យនាពេលថ្មីៗនេះ ប្រទេសកម្ពុជាអាចបន្តអនុវត្តវិធានការកាត់បន្ថយហានិភ័យផ្សេងទៀតដើម្បីពង្រីកការវិនិយោគលើវិស័យនេះ។ សម្រាប់ថាមពលពន្លឺព្រះអាទិត្យខ្នាតធំសម្រាប់ផលិតកម្មអគ្គិសនី កម្មវត្ថុសំខាន់គឺបង្កើត/

[៥] ADB កំពុងជួយរដ្ឋាភិបាលក្នុងការសិក្សាពីសមត្ថភាពនៃបណ្តាញអគ្គិសនីរដ្ឋក្នុងការភ្ជាប់ថាមពលពន្លឺព្រះអាទិត្យ (និងមធ្យោបាយជំនួយបណ្តាញអគ្គិសនីរដ្ឋដែលចាំបាច់ដើម្បីធានាស្ថិរភាពនិងភាពទុកចិត្តបាន) ព្រមទាំងបង្កើតដំណើរការក្នុងការការដេញថ្លៃជាសាធារណៈសម្រាប់គម្រោងថាមពលពន្លឺព្រះអាទិត្យសម្រាប់ផលិតកម្មអគ្គិសនី។

[៦] 3i កំពុងជួយរដ្ឋាភិបាលក្នុងការសិក្សាពីការភ្ជាប់តង់ស្យុងទាបសម្រាប់ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ

គ្រប់គ្រងទីផ្សារមួយដែលមានតម្លាភាពនិងប្រកួតប្រជែងដោយស្មើភាព។ សម្រាប់ថាមពលពន្លឺព្រះអាទិត្យដាក់លើដំបូលអគារ បទបញ្ញត្តិថ្មីដែលទើបបានអនុម័ត គួរគ្របដណ្តប់លើវិស័យគេហដ្ឋាន និងអាជីវកម្មខ្នាតតូចផងដែរ។

- **ឌីជីថលភាវូបនីយកម្ម និងគំរូអាជីវកម្មបែបថ្មីជួយបង្កើតឱកាសទីផ្សារសម្រាប់ប្រព័ន្ធដែលមិនតភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ៖** សម្រាប់ប្រព័ន្ធដែលមិនតភ្ជាប់នឹងបណ្តាញអគ្គិសនីរដ្ឋ របាយការណ៍នេះសន្មតយកម៉ូដែលថ្មីដែលប្រើប្រាស់ឌីជីថលនិងនាំមុខដោយវិស័យឯកជន សម្រាប់អនុវិស័យពីរគឺបណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើថាមពលពន្លឺព្រះអាទិត្យនិងអាគុយ និងប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះដែលបង់ថ្លៃរំលោះតាមរបៀប “pay-as-you-go”។ តាមរយៈបទពិសោធន៍នៅប្រទេសដទៃ វិធីសាស្ត្រទាំងនេះមានប្រសិទ្ធភាពខ្ពស់ក្នុងការបង្កើនកម្រិតការវិនិយោគ។ វិធានការកាត់បន្ថយហានិភ័យគួរតែធ្វើជាជំហាន/ដំណាក់កាលៗ ខណៈពេលដែលទីផ្សារ (នៃអនុវិស័យទាំងនេះ) អាចវិវត្តន៍ទៅរកភាពចាស់ទុំ។ ម៉ូដែលនៃការវិភាគនេះរកឃើញ ថាអនុវិស័យនិមួយៗចាំបាច់ត្រូវការឧបត្ថម្ភធនដោយផ្ទាល់ក្នុងបរិមាណតិចតួចព្រោះអនុវិស័យទាំងនេះកំពុងស្ថិតនៅដំណាក់កាលចាប់ផ្តើមហើយអគ្គិសនីភាវូបនីយកម្មផ្តល់ប្រយោជន៍ដល់សាធារណជនផងដែរ។ ការវិភាគដដែលនេះបង្ហាញទៀតថា ប្រជាជនប្រមាណ១.៨លាននាក់នឹងទទួលនូវកំរិតអគ្គិសនីល្អប្រសើរជាងមុននៅត្រឹមឆ្នាំ២០៣០ ប្រសិនបើវិធានការទាំងនេះត្រូវបានអនុវត្ត។ របាយការណ៍នេះពុំមានបំណងផ្តល់អាទិភាពលើអនុវិស័យណាមួយនោះឡើយ ប៉ុន្តែចង់ផ្តល់ជាអនុសាសន៍ថា ការជ្រើសរើសអនុវិស័យណាមួយគួរផ្អែកលើដង់ស៊ីតេប្រជាជន និង កម្រិតអគ្គិសនីភាវូបនីយកម្មដែលចង់ផ្តល់ទៅអោយប្រជាជននៅតំបន់នោះ៖
    - បណ្តាញអគ្គិសនីខ្នាតតូចដែលប្រើប្រាស់ថាមពលពន្លឺព្រះអាទិត្យនិងអាគុយសក្តិសមចំពោះតំបន់មានដង់ស៊ីតេប្រជាជនខ្ពស់ ផ្តល់សក្តានុពលសម្រាប់ផ្នែកផលិតកម្ម និងអាចផលិតថាមពលបានច្រើនប៉ុន្តែមានតម្រូវការរៀបចំបទបញ្ញត្តិច្រើន។
    - ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះដែលបង់ថ្លៃរំលោះតាមរបៀប “pay-as-you-go” ស័ក្តិសមសម្រាប់អ្នកប្រើប្រាស់នៅតំបន់ដាច់ស្រយាល។ ប្រព័ន្ធថាមពលពន្លឺព្រះអាទិត្យតាមផ្ទះមានតម្រូវការផ្នែកបទបញ្ញត្តិតិចតួចយ៉ាងហោចណាស់ក៏នៅក្នុងដំណាក់កាលដំបូងៗនៃការអភិវឌ្ឍទីផ្សារដែរ។

អនុសាសន៍ និងជំហានបន្ទាប់

- **កិច្ចពិគ្រោះយោបល់ជាមួយនឹងតួអង្គពាក់ព័ន្ធ និងការស្រាវជ្រាវបន្ថែម៖**
    - ការវិភាគនិងលទ្ធផលក្នុងរបាយការណ៍នេះគួរតែលើកយកមកពិភាក្សាបន្ថែម និងចែករំលែកជាមួយនឹងស្ថាប័នរដ្ឋាភិបាលនិងអ្នកពាក់ព័ន្ធសំខាន់ៗផ្សេងទៀត។ របាយការណ៏នេះមិនមែនផ្តល់ត្រឹមតែតួលេខនោះទេ ប៉ុន្តែវាផ្តល់នូវលទ្ធផលប្រកបដោយតម្លាភាព ធាតុចូល និងតម្លៃសន្មត ដើម្បីចូលរួមចំណែកក្នុងដំណើរការរៀបចំគោលនយោបាយដែលផ្អែកលើព័ត៌មានគ្រប់គ្រាន់។

  - ជាមួយគ្នានេះផងដែរ របាយការណ៍នេះក៏បានកំណត់នូវជំហានបន្ទាប់សម្រាប់ការស្រាវជ្រាវ ដើម្បីឱ្យការវិភាគបច្ចេកទេសកាន់តែស៊ីជម្រៅ។

- **ប្រសិនបើប្រទេសកម្ពុជាចង់អភិវឌ្ឍផ្នែកថាមពលពន្លឺព្រះអាទិត្យអោយឆាប់រហ័ស ប្រទេសនេះគួរ៖**
  - ប្រទេសកម្ពុជាអាចជ្រើសរើសប្រើប្រាស់វិធីសាស្ត្រខាងក្រោមសម្រាប់អនុវិស័យនិមួយៗក្នុងចំណោមអនុវិស័យទាំងបួនខាងលើ៖
    - ***វិធីសាស្ត្របែបទូលំទូលាយ៖*** អនុវត្តវិធានការសាធារណៈទាំងអស់ដើម្បីកាត់បន្ថយហានិភ័យដូចដែលបានរៀបរាប់ខាងលើ។
    - ***វិធីសាស្ត្រផ្ដោតលើតែចំណុចអាទិភាព៖*** អនុវត្តត្រឹមតែវិធានការសាធារណៈកាត់បន្ថយហានិភ័យដែលជាអាទិភាពប៉ុណ្ណោះ។

សកម្មភាពទាំងនេះគួរតែអនុវត្តដោយមានផែនទីចង្អុលផ្លូវមួយ និងដោយមានការសម្របសម្រួលជាមួយនឹងក្រសួងពាក់ព័ន្ធ ដៃគូរអភិវឌ្ឍន៍ និងអ្នកផ្តល់ជំនួយនានា។

Key Points for Decision Makers[7]

Why Solar PV in Cambodia?

- **Cambodia has strong potential for solar photovoltaic (PV) energy:** solar PV provides the opportunity to meet Cambodia's rapidly growing electricity demand in a sustainable way, improve energy security in line with Rectangular Strategy Phase IV[8] as well as to advance Cambodia's electrification via innovative off-grid technologies and business models. Solar PV can also support Cambodia's contributions to addressing climate change under the United Nations climate agreements.

Goal of this report

- **Identifying cost-effective derisking measures:** the objective of this report is to analyze the most cost-effective public derisking measures to support private sector investment in solar PV energy in Cambodia. The report performs a rigorous, quantitative modelling exercise, based on private sector data and interviews. All the report's financial models, data and assumptions used in the modelling are publicly available.

- **Analyzing four sub-sectors:** taking a comprehensive approach to the solar PV opportunity, the report analysis four different solar PV sub-sectors:
  - **on-grid:** (i) utility-scale PV and (ii) rooftop PV;
  - **off-grid:** (iii) solar-battery mini-grids and (iv) solar home systems.

- **Achieving private investment targets:** for each sub-sector, the report uses illustrative private sector investment targets for solar PV:
  - **on-grid:** 2030 targets of 350 Megawatt (MW) for both utility-scale PV and rooftop PV, totalling 700 MW[9]. This equates to 20% of Cambodia's estimated installed capacity in 2030;
  - **off-grid:** 2025 'building block' targets of 10 MW each for solar-battery mini-grids and pay-as-you-go solar home systems. It is estimated there is a total market opportunity of between four to six 10 MW 'building blocks'.

Key results

- **Over USD 900 million investment opportunity in solar PV:** Cambodia has the potential to attract significant private sector investment in solar PV, estimated at USD 903 million[10] across the four solar PV sub-sectors to achieve the report's targets.

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7 This 'Key points for decision makers' section summarizes the findings of the report in a succinct manner. As such, references have not been included in this section but are found later in the relevant sections of the full report.

8 Rectangular Strategy Phase IV calls for "continuing to encourage and increase investment in clean energy and renewable energy, especially solar power while reducing the production of energy from unclean sources to ensure long-term energy security."

9 The target of 350 MW each for solar rooftop PV and utility scale PV (total 700 MW) is not an official target set by the government of Cambodia, but an assumption from the authors based on international experiences and consultations with government and stakeholders. In addition, it does not imply that the current grid can technically absorb 700 MW of variable renewable energy (VRE) sources. It is an assumption to allow for carrying out the financial and economic modelling, assuming that the grid will gradually be upgraded over time allowing for a higher percentage of VRE to be added without affecting grid stability. The new power development plan that will be prepared in 2019 will determine the share of various renewable energy sources into the power grid.

10 The overall investment opportunity assumes the realization of 350 MW utility-scale PV, 350 MW rooftop PV (commercial, industrial and residential sector), 3 x 10 MW solar-batter MG building blocks, and 3 x 10 MW SHS building blocks.

- **Low solar PV generation costs:** Solar PV is an increasingly cost-competitive technology in all four sectors. Derisking utility-scale PV investments leads to solar PV generation costs lower than a future coal and hydro baseline energy generation mix.

- **Derisking brings clear benefits for Cambodia:** for each of the four solar PV sub-sectors, the report recommends a comprehensive package of public derisking measures to systematically target investment risks. In turn, the modelling identifies a number of resulting benefits, **including increased investment, economic savings, improved tariff affordability, access to electricity and lower greenhouse gas emissions.** Across all sub-sectors, the modelling results clearly demonstrate that implementing derisking measures is cost-effective. In total, across all four sub-sectors, this creates economic savings[11] of USD 146 million[12]. *Table 1* below lists the increased investment and economy-wide savings for each sub-sector.
  - For example, for utility-scale PV, the report models a package of 20 recommended public derisking measures, estimated at a cost of USD 39 million until 2030. It is estimated that this will catalyze USD 280 million in private sector investment and result in economic savings of USD 60 million.

Table 1: Investment and savings from derisking packages for solar PV in Cambodia, all four sub-sectors

PARAMETER	ON-GRID		OFF-GRID	
	UTILITY-SCALE PV (USD)	ROOFTOP PV[13] (USD)	SOLAR-BATTERY MINI-GRIDS[14] (USD)	SOLAR HOME SYSTEMS[15] (USD)
Private Sector Investment	280m	339m	35m	12m
Savings From Derisking	60m	61m	18m	7m
Public Cost of Derisking	39m	16m	10m	3m
Recommended Package of Derisking Measures	20 measures (17 policy, 3 financial)	18 measures (17 policy, 1 financial)	18 measures (15 policy, 3 financial)	17 measures (15 policy, 2 financial)

- **Priority derisking measures:** the report identifies – based on qualitative feedback received from investors – priority derisking measures for each sub-sector. *Table 2* lists these priority measures. Investors state that these measures will be the most critical to unlocking low-cost investment at scale.

[11] Economic savings represent the total, net present value of savings from lower generation cost of electricity due to derisking over the lifetime of the solar PV assets.

[12] Total economic savings assume the realization of 350 MW utility-scale PV, 175 MW rooftop PV (C&I only), 1 x 10 MW solar-batter MG building block, and 1 x 10 MW SHS building block.

[13] The overall investment target for rooftop PV of 350 MW has been divided equally into 175 MW in the commercial and industrial (C&I) sector and 175 MW in the residential sector. Except for the total capital investment costs, the report's modelling is solely performed on rooftop PV for the C&I sector and does not further refer to the residential sector.

[14] Results refer to 1 x 10 MW solar-battery MG building block.

[15] Results refer to 1 x 10 MW SHS building block.

Table 2: Priority derisking measures based on investor feedback for solar PV in Cambodia, all four sub-sectors

SOLAR PV SUB-SECTOR	PRIOIRITY DERISKING MEASURES
Utility-Scale PV	• Implement a transparent and competitive auction mechanism, with a standardized Power Purchase Agreement (PPA)[16] • Perform grid stability studies, transparently share findings; technical support and software for grid management
Rooftop PV	• Expansion of regulations to low-voltage customers, including balanced solar capacity charges[17] • Policies allowing export of power to the grid, for instance via net-metering or feed-in tariff
Solar-Battery Mini-Grids	• Strengthen capacities of existing government bodies/establish a government body or unit to advance/oversee/improve off-grid electrification • Implement a dual regulatory regime (comprehensive & light-touch), including license • Extend current policies on digitalization, including stronger rural cellular coverage and competitive mobile money
Solar Home Systems	• Develop and enforce technology guidelines/standards for solar home system equipment • Extend current policies on digitalization, including stronger rural cellular coverage and competitive mobile money

- **Transparent and further liberalized regulations can advance on-grid investment:** for on-grid, solar PV can assist Cambodia in meeting its growing power demand and improving its energy security, including reducing seasonal imports. Following recent initial investments and policies, Cambodia can now implement further derisking measures to scale-up investment. In utility-scale PV, a main objective could be to put in place a fully competitive and transparent regulated market. In rooftop PV, the opportunity is to expand the recent regulations to the residential and small-business sectors.

- **Digitalization and new business models create off-grid opportunity:** for off-grid, the report assumes new, private sector, digitally-oriented models for both sub-sectors: solar-battery mini-grids and pay-as-you-go solar home systems. These new approaches are highly promising, having demonstrated rapid levels of investment in other countries. Derisking measures will likely need to be phased out as each market evolves and matures. The modelling assumes that limited direct grant subsidies will be required given the early-stage of each sub-sector and the public-good nature of electrification. The modelling assumes that 1.8 million people in 2030 can achieve improved electricity access via these approaches. This report does not prioritize one sub-sector over another and recommends selection based on density of population and desired level of electricity:
    - solar-battery mini-grids are suited to more dense populations. They offer the potential for productive use and higher generation capacity, but also require well-designed regulations;
    - pay-as-you-go solar home systems are suited to dispersed end-users. Solar home systems appear to need minimal regulatory support, at least in early phases of market development.

[16] ADB is currently supporting RGC on a study to determine the ability of the grid to absorb solar energy (and the grid enhancement measures needed to ensure reliability and stability) as well as to establish a process for a competitive bidding process for utility-scale PV projects.

[17] 3i is currently supporting RGC on a study on low-voltage connections of rooftop PV systems.

Recommendations and next steps

- **Stakeholder consultation and follow-up research**
  - The analysis and findings in this report can be further discussed and shared among government agencies and other key stakeholders. The intent of this report is not to provide a predominant result, but to provide transparent findings, inputs and assumptions, so that they can contribute to an informed design process.
  - Relatedly, the report identifies a number of possible follow-up modelling and research steps to deepen the technical analysis.
- **Possible actions if Cambodia wishes to advance immediately with solar PV**
  - Cambodia can proceed with the following for each of the four sub-sectors:
    - *Comprehensive approach:* implement the suggested package of public derisking measures;
    - *Focused approach:* implement certain priority derisking measures only.

Actions can be guided by an implementation road map and in coordination among ministries and with international partners, and donors.

Executive Summary

Executive Summary

Overview

The objective of this report is to analyze the most cost-effective public derisking measures to support private sector investment in on-grid and off-grid solar photovoltaic (PV) energy in Cambodia.

Taking a comprehensive approach, the report analysis four different solar PV sub-sectors:

- **on-grid:** (i) utility-scale PV and (ii) rooftop PV;
- **off-grid:** (iii) solar-battery mini-grids (solar-battery MG) and (iv) solar home systems (SHS).

The report presents the results from a quantitative and investment-risk informed modelling analysis. Modelling data has been obtained from the recent literature and structured interviews with private sector investors and developers. This report was prepared in collaboration with the National Council for Sustainable Development (NCSD) of Cambodia, reviewed by the Ministry of Mines and Energy (MME), and Ministry of Economy and Finance (MEF).

Context and Opportunity for Solar PV in Cambodia

Cambodia's power sector is characterized by rising electricity demand, the dominance of coal- and hydro-based power generation and energy imports from neighboring countries, particularly during dry season. Cambodia's power market is liberalized, with independent power producers (IPPs) significantly embedded in the country's power generation landscape. Cambodia has approximately 2,300 MW in power generation capacity[18], with 81% of total power generation originating from hydro and coal (MME, 2018). Solar PV and biomass only contributes marginally to the country's power generation. The national consumer grid tariffs for 2019-2020 range from USD 9.5 to 18.25 cents per kWh[19], depending on consumer type (industry, commercial, residential or specially subsidized consumers) and purchase conditions, and/or voltage connections (low, medium, high) (EAC, 2018). Electricity subsidies are provided for rural, low-income households, schools, hospitals and referral health care centers. Overall, annual demand is projected to increase rapidly by 10-20% up to 2020 and beyond (MME, 2016).

Cambodia has made rapid progress in increasing the access to electricity for villages, households and other consumers. 97.6% of Cambodian households have access to at least once source of electricity, with 71.5% having access to grid electricity and 26.1% to off-grid electricity (World Bank, 2018). Most non-grid connected households either use rechargeable car batteries charged at village charging stations, or self-owned, basic SHS systems, which can power low-load appliance such as a small television or fan. Very few households use solar lanterns or solar lighting systems, which typically provide only lighting and phone charging (World Bank, 2018). Going forward, Cambodia aims to provide basic electricity access to all villages by 2020 and grid-quality electricity access to 90% of all households by 2030 (MME, October 2017).

[18] Includes power generation capacity from electricity imports from neighboring countries. Cambodia's national installed generation capacity in 2017 was 1,900 MW.

[19] During finalization of this report in December 2018, the Government of Cambodia has announced to accelerate the national electricity reduction plan 2019-2020, effectively reducing the electricity retail tariffs for different consumer groups. Furthermore, EAC and MME have been advised to look into further electricity tariff reductions starting from 2021. The tariff reduction will be financed through a USD 50 million government subsidy to the electricity sector. For details on electricity tariffs, see Annex B.

Cambodia has abundant solar resources and high solar potential. There are currently no official targets for solar PV in Cambodia[20]. This report thus uses illustrative long term, private sector investment targets for solar PV. The report's on-grid target is set at 700 MW[21] by 2030, split equally between utility-scale PV and rooftop PV. For off-grid electrification, for each of the two off-grid sub-sectors – solar-battery MGs and SHS – the report uses illustrative 'building block' targets of 10 MW[22] by 2025.

With abundant solar resources, Cambodia is well positioned for investment in solar PV projects. Solar PV provides the opportunity to meet Cambodia's rapidly growing electricity demand[23], improve energy security, to advance Cambodia's electrification via innovative off-grid technologies and business models, and can also support Cambodia's contributions to addressing climate change under the United Nations Framework Convention on Climate Change (UNFCCC).

Financing Costs and Risk Environment

The report's modelling performs a detailed analysis of the financing costs and risk environment for all four solar PV sub-sectors in Cambodia today. Primary data was obtained from interviews with project developers and international investors. The findings for utility-scale PV are illustrated below.

- Based on data from interviews focusing on the risk environment of utility-scale PV, the report finds that private sector financing costs for utility-scale today are 15% for the cost of equity (CoE) and 9% for the cost of debt (CoD). They are substantially higher than in the best-in-class country for utility-scale PV – Germany – where financing costs are estimated at 7% CoE and 3% CoD. In addition, investors in Cambodia are also facing less attractive capital structures (debt to equity ratios).

- Cambodia's higher financing costs reflect a range of investment risks for utility-scale PV investments *(Figure 1)*. The risk categories with the largest impact on elevated financing costs are (i) power market risk, related to uncertainty in the outlook and official targets for utility-scale PV, and absence of a standardized tendering process; and (ii) grid/transmission risk, arising from the lack of clarity on Cambodia's grid absorption capacity for RE and transmission line planning.

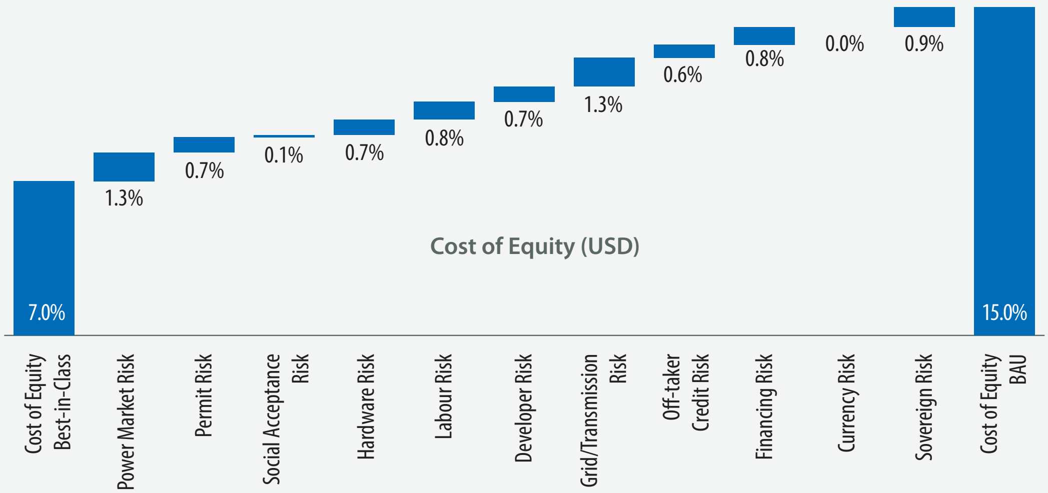
[20] Cambodia's National Determined Contribution (NDC) and the Rectangular Strategy - Phase 4 identifies investments in clean energy and renewable energy, especially solar power as priority. However, not quantitative target has been determined yet.

[21] 700 MW equates to approximately 20% of anticipated 2030 total installed capacity in Cambodia. The target of 350 MW each for solar rooftop PV and utility scale PV (total 700 MW) is not an official target set by the government of Cambodia, but an assumption from the authors based on international experiences and consultations with government and stakeholders. In addition, it does not imply that the current grid can technically absorb 700MW of variable renewable energy (VRE) sources. It is an assumption to allow for carrying out the financial and economic modelling, assuming that the grid will gradually be upgraded over time allowing for a higher percentage of VRE to be added without affecting grid stability. The new power development plan that will be prepared in 2019 will officially determine the share of various renewable energy sources into the power grid.

[22] These illustrative 10 MW building blocks targets will need to be multiplied to achieve Cambodia's electrification objectives. Based on current population projections and the government's 90% household level electrification objective for 2030, there will be approximately 1.9 million non-grid-connected households in 2030. For example, the 10 MW solar-battery MG provides electricity access to approximately 49,000 households.

[23] Including the potential utilization of complementarity with hydropower-based electricity generation.

Figure 1: Impact of risk categories on financing costs for utility-scale PV investments in Cambodia, business-as-usual (BAU) scenario



Source: Interviews with utility-scale PV investors and developers; modelling; best-in-class country for utility-scale PV is assumed to be Germany; see Annex A for details of assumptions and methodology.

The results of analysis on financing costs and risk environments for the other three solar PV sub-sectors analyzed in this study can be found in Chapter 6 (rooftop PV), Chapter 7 (solar-battery MG) and Chapter 8 (SHS).

Public Derisking Measures

For each solar PV sub-sector, the modelling examines the selection and cost-effectiveness of public derisking measures to meet the report's investment targets. Public derisking measures can be understood as interventions by the government and its partners that address specific investment risks, in the form of policies, programs or financial products.

On-Grid: Utility-Scale PV

For utility-scale PV (2030 investment target: 350 MW) the modelling assumes a build-own-operate business model with project finance and a typical power plant size of 30-100 MW.

The modelling identifies a comprehensive, targeted set of public derisking measures for utility-scale PV, as set out in *Table 3*. These are estimated to cost USD 39 million until 2030.

Table 3: Selection of public instruments to achieve the investment targets for utility-scale PV

RISK CATEGORY	POLICY DERISKING INSTRUMENTS	FINANCIAL DERISKING INSTRUMENTS
Power Market Risk	• Establish long term on-grid PV targets • Strengthen capacities of independent market regulator • **Implement auction model** • **Develop standardized and well-designed PPA** document and process[24]	N/A
Permit Risk	• Streamline permitting/grid connection processes • Review and improve land administration	N/A
Social Acceptance Risk	N/A	N/A
Hardware Risk	• Streamlined, consistent and facilitated customs procedures; considered approach to customs tariffs • Develop certification and technology standards, and enforce standards	N/A
Digital Risk	N/A	N/A
Labor Risk	• Programs to develop a competitive, skilled labor market in solar PV (all roles)	N/A
Developer Risk	• Support to grow early-stage industry	N/A
Grid/Transmission Risk	• Develop a grid code for new renewable energy (RE) technologies/solar PV • **Develop and disseminate grid management study; technical support and software on grid management and planning** • Establish response timing targets for connection of new renewable/solar PV sources to the grid	• Include a "take-or-pay" clause in the standard PPA[25]
Off-taker Credit Risk	• Establish international best practice in off-taker's management and operations; implement sustainable cost recovery policies	• Government and/or development bank guarantees for PPA payments
Financing Risk	• Reform domestic financial sector for green infrastructure investments • Expand options to meet collateral requirements for domestic lending to businesses • Strengthen domestic investors' familiarity with and capacity regarding solar PV	• Public loans to utility-scale solar developers[26]
Currency Risk	N/A[27]	N/A
Sovereign Risk	N/A	N/A

Source: Modelling. See Annex A for a full description of these instruments. "N/A" indicates "Not Applicable". Bold text represents high-priority instruments.

[24] ADB is currently supporting RGC on a study to determine the ability of the grid to absorb solar energy (and the grid enhancement measures needed to ensure reliability and stability) as well as to establish a process for a competitive bidding process for utility-scale PV projects.

[25] A "take-or-pay" clause is a clause found in a Power Purchase Agreement (PPA) that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver the electricity generated by its renewable energy plant.

[26] The source of the public loan is likely to be an international multilateral or bilateral agency.

[27] Not applicable because local currency is directly linked to USD.

When implemented, the public derisking efforts lower financing costs and result in the following potential benefits:

- catalysing USD 280 million in private sector investment in utility-scale PV;
- lowering utility-scale PV generation costs due to derisking from USD 10.5 cents to USD 8.7 cents per kWh;
- creating economic savings related to derisking of utility-scale solar PV of USD 60 million over 25 years;
- reducing emissions by 5.5 million tonnes of CO_2 over 25 years, relative to the baseline.

Investors provided further qualitative feedback identifying the key priority derisking measure for utility-scale PV as the development and implementation of a transparent and competitive auction mechanism, with an accompanying standardized PPA. Furthermore, performing a grid stability study and transparently share findings has been highlighted as a priority measure.

On-Grid: Rooftop PV

For rooftop PV (2030 investment target for commercial and industrial (C&I): 175 MW[28]) the modelling assumes a third-party ownership business model (25-year leases to end-users) with rooftop PV systems sized between 200 kilowatt-peak (kWp) and 2 megawatt-peak (MWp), and without battery storage. Financing will typically be corporate finance, with the possibility for off-balance sheet aggregative financing.

The modelling identifies a comprehensive, targeted set of public derisking measures for rooftop PV, as set out in *Table 14* in the report. These instruments are estimated to cost USD 16 million until 2030.

When implemented, the public derisking efforts lower financing costs and result in the following potential benefits:

- catalyzing USD 152 million in private sector investment in rooftop PV (C&I only)
- lowering rooftop PV (C&I) generation costs due to derisking from USD 13.5 cents to USD 10.1 cents per kWh
- creating economic savings related to derisking of rooftop PV (C&I) of USD 61 million over 20 years
- reducing emissions by 2.8 million tonnes of CO_2 over 25 years, relative to the baseline

Investors provided further qualitative feedback. The Electricity Authority of Cambodia's (EAC) recent regulation for captive-use rooftop PV systems in Cambodia is considered an important step to attract private investment, particularly for larger, high-voltage systems. Investors identified two priority derisking measures going forward: (i) the expansion of the regulations to include eligibility for low-voltage customers, including balanced solar capacity charges; and (ii) in the medium/longer term, the introduction of, for instance, a net-metering or feed-in-tariff (FiT) scheme.

[28] The overall investment target for rooftop PV of 350 MW has been divided equally into 175 MW in the commercial and industrial (C&I) sector and 175 MW in the residential sector. Except for the total capital investment costs, the report's modelling is solely performed on rooftop PV for the C&I sector and does not further refer to the residential sector.

Off-Grid: Solar-Battery Mini-Grid (MG)

For solar-battery MG, the report takes a building block[29] approach to targets, with an illustrative solar-battery MG building block target of 10 MW until 2025. The modelling assumes a generic mini-grid system size of 20 kWp solar modules and 60 kilowatt-hour (kWh) battery storage (lithium-ion), serving 100 households to Tier 1-2 service levels[30] while supporting additional productive use activities for businesses and schools. The modelling further assumes a private sector, digitally-oriented business model, using a build-own-operate approach and with each private sector developer aggregating multiple mini-grid sites. Financing will typically be corporate finance, with the possibility for off-balance sheet aggregative financing.

The modelling identifies a comprehensive, targeted set of public derisking measures for solar-battery MG, as set out in *Table 21* in the report. These instruments are estimated to cost USD 10.3 million, including a direct subsidy of USD 2.9 million, until 2025.

When implemented, the public derisking efforts lower financing costs and result in the following potential benefits for each 10 MW building block:

- serving 231,000 people to Tier 1-2 levels, with additional productive use for businesses and social entities;
- catalyzing USD 35 million in private sector investment in solar-battery MG;
- creating economic savings of USD 18 million in solar-battery MG over 20 years;
- lowering the average daily household energy spend via solar-battery MG due to derisking from USD 50 cents to USD 40 cents per day, and below the cost of diesel mini-grids;
- reducing emissions by 210 kilotonnes of CO_2 over 20 years, relative to the baseline.

Investors provided further qualitative feedback. It is recognized that digitally-oriented models envisaged for solar-battery MGs in Cambodia are currently absent and that it will require significant, and coordinated public derisking measures to create a favorable investment environment. Investors identified three priority derisking measures: (i) the strengthening of or establishment a government body or unit with a clear mandate to advance, improve and oversee off-grid electrification; (ii) the implementation of a dual regulatory regime (comprehensive and light touch[31]), including off-grid electrification areas and licenses; (iii) policies supporting digitalization, including cellular coverage in rural areas, and a competitive mobile money marketplace.

[29] 10 MW building blocks targets can be multiplied.

[30] Tier 1-2 service levels equal 4 hours of limited access to small quantities of electricity, allowing the use of low-load appliances such as basic cell-phone charger, lights, fan or television.

[31] The dual regulatory regime offers solar-battery MG developers the opportunity to conduct their business in one of two regulatory environments: (i) light-touch regulatory framework, with only minimal regulatory requirements, i.e. simple online self-registration, no tariff controls, no concession requirement, and only minimal reporting. However, under this regime, project developers do not receive exclusivity for a certain concession area and do not have access to government financial incentives; (ii) comprehensive regulatory framework; which operates under well-designed, exclusive concessions (e.g. size, years, targets) in determined areas, under regulated tariffs, technical standards and quality and reporting requirements. Project developers under this regime have also access to specific government financial incentives such as concessional loans or grant contributions.

Off-Grid: Solar Home Systems

For Solar Home Systems (SHS), similar to solar-battery MG, the report takes a building block[32] approach to targets, with an illustrative SHS building block target of 10 MW until 2025.

The modelling assumes generic 100 watt-peak (Wp) SHS units including battery storage and a kit of energy-efficient household appliances[33], to an approximate Tier 1-2 service level. The modelling further assumes a pay-as-you-go (PAYG) digital business model, with mobile money, and with SHS companies offering 3-year lease-to-own arrangements with households. Financing will typically be corporate finance, with the possibility for off-balance sheet aggregative financing.

The modelling identifies a comprehensive, targeted set of public derisking measures for SHS, as set out in *Table 29* in the report. These instruments are estimated to cost USD 3 million, including a direct subsidy of USD 1.2 million, until 2025.

When implemented, the public derisking efforts lower financing costs and result in the following potential benefits for each 10 MW building block:

- serving 470,000 people (100,000 households) to Tier 1-2 levels, with energy efficient appliances included in the package;
- catalyzing USD 12 million in private sector investment in SHS developers;
- creating economic savings of USD 7 million in SHS over 10 years;
- lowering average household daily energy spend via SHS due to derisking from USD 1.13 to USD 1.04 per day (including the access to and use of energy efficient appliances);
- reducing emissions by 140 kilotonnes of CO_2 over 20 years, relative to the baseline.

Investors provided further qualitative feedback, identifying two priority derisking measures: (i) policies supporting digitalization, including cellular coverage in rural areas and a competitive mobile money marketplace; (ii) developing and enforcing technology standards for SHS equipment.

[32] 10 MW building blocks targets can be multiplied.

[33] Please see Annex A for details on energy efficient appliances included in the modelling[28] 10 MW building blocks targets can be multiplied.

Conclusions

Table 4 below provides a comprehensive overview of the modelling results across all four solar PV sub-sectors analyzed in this report.

Table 4: Summary of modelling results across all four solar PV sub-sectors

PARAMETER		UTILITY-SCALE PV	ROOFTOP PV[34]	SOLAR-BATTERY MG[35]	SOLAR HOME SYSTEMS[36]
Targeted Installed Capacity		350 MW	350 MW	10 MW	10 MW
Target Year		2030	2030	2025	2025
Total Investment Costs (Capital)		280m	339m	35m	12m
Total Investment Costs (Hardware)		N/A	N/A	N/A	47.5m[37]
Hardware Costs		0.8/Wp	0.9/Wp	3.5/Wp	12.0/Wp
LCOE (Utility-scale, Rooftop PV)/Daily Energy Spend (MG, SHS	Pre-Derisking	0.105/kWh	0.135/kWh	0.50/hh[38]/day	1.13/hh/day
	Post-Derisking	0.087/kWh	0.101/kWh	0.40/hh/day	1.04/hh/day
Cost – Policy Derisking Instruments (USD)		6.4m	7.2m	2.3m	1.1m
Cost – Financial Derisking Instruments (USD)		32.8m	8.6m	5.1m	0.5m
Cost – Direct Financial Incentives (USD)		N/A	N/A	2.9m	1.2m
Financing Cost – Cost of Equity	Pre-Derisking	15.0%	17.0%	19.0%	19.0%
	Post-Derisking	12.0%	14.5%	16.7%	16.9%
Financing Cost – Cost of Debt	Pre-Derisking	9.0%	10.0%	11.0%	11.0%
	Post-Derisking	6.7%	8.4%	9.7%	9.7%
Capital Structure – Pre-Derisking		Debt: 50% Equity: 50%	Debt: 25% Equity: 75%	Debt: 0% Equity: 100%	Debt: 0% Equity: 100%
Capital Structure – Post-Derisking		Debt: 75% Equity: 25%	Debt: 75% Equity: 25%	Debt: 50% Equity: 50%	Debt: 50% Equity: 50%
Carbon Abatement		5.5 $mtCO_2e$	2.8 $mtCO_2e$	210 $ktCO_2e$	140 $ktCO_2e$

Overall, Cambodia has the potential to attract significant private sector investment in solar PV, totalling USD 903 million[39] across the four solar PV sub-sectors to achieve the report's targets. The total public cost of

[34] The overall investment target for rooftop PV of 350 MW has been divided equally into 175 MW in the commercial and industrial (C&I) sector and 175 MW in the residential sector. Except for the total capital investment costs, the report's modelling is solely performed on rooftop PV for the C&I sector and does not further refer to the residential sector.

[35] Results refer to 1 x 10 MW solar-battery MG building block.

[36] Results refer to 1 x 10 MW SHS building block.

[37] A total of USD 47.5 million is leveraged for hardware investments over the entire 10-year SHS investment lifetime. Due to the 3-year lease term business model, which effectively refinances hardware investments every three years, the actual capital need for SHS project developers is USD 12 million.

[38] hh = households.

[39] The overall private sector investment potential comprises the total capital and hardware investments costs across all sub-sectors and assumes six 10 MW off-grid investment blocks for solar-battery MG and SHS (three for solar-battery MG and three for SHS). The number of assumed off-grid investment blocks addresses the non-grid connected market. If the non-grid connected market is excluded, i.e. only one solar-battery MG and one SHS building block is assumed, the overall private sector investment potential is USD 714 million.

derisking measures and financial incentives is estimated at USD 68 million[40, 41], leading to USD 146 million in economic savings, resulting in significant improvements in affordability, and emission reductions of 8.7 million tonnes of CO_2 over 25 years[42].

For on-grid, solar PV can assist Cambodia in meeting its growing power demand and improving its energy security, including reducing seasonal imports. Following recent initial investments and policies, Cambodia can now implement further derisking measures to scale-up investment. In utility-scale PV, a main objective can be to put in place a fully competitive and transparent regulated market. In rooftop PV, the opportunity is to expand the recent regulations to residential and small-business sectors and consider revising the recently introduced solar capacity charge in order to create a balanced level-playing field with other technologies.

For off-grid, the report assumes new, private sector, digitally-oriented models for both solar-battery MGs and pay-as-you-go SHS. These new models are promising, having demonstrated rapid levels of investment in other countries, in particular in East Africa and India. Derisking measures will likely need to be phased, as each sub-sector evolves and matures. The modelling assumes that direct grant subsidies will be required given the early-stage of each sub-sector and the public-good nature of electrification.

This report is neutral between the two sub-sectors and recommends that the selection of technologies is based on further geo-spatial modelling, and other considerations:

- solar-battery MGs are suited to more dense populations, offer the potential for productive use and higher generation capacity, but also require well-designed regulations;
- pay-as-you-go SHS are suited to dispersed end-users. SHS appears to need minimal regulatory support, at least in early phases of market development.

Promoting investment in each solar PV sub-sector will require the implementation of its specific package of derisking measures, as set out in the report. Simultaneously, there are commonalities across sectors and the opportunity to create efficiencies via derisking measures that address multiple sub-sectors at once. Three areas of public derisking measures have benefits across all sub-sectors:

- supporting, via training and certification, a high-quality private sector workforce in solar PV, including technical staff, and engineering, procurement and construction (EPC) contractors;
- supporting, for example via early financial aid to industry associations, a competitive domestic market in private sector developers in solar PV;
- reform the domestic financial sector, to support lending and low-cost financing for renewable energy (RE) in local currency;
- developing official RE and solar PV targets to clarify investment potential and national grid integration requirements.

[40] Includes direct financial incentives for off-grid sources.

[41] Total public cost of derisking measures and financial incentives, total economic savings and total emission reductions assume the realization of 350 MW utility-scale PV, 175 MW rooftop PV (C&I only), 1 x 10 MW solar-batter MG building block, and 1 x 10 MW SHS building block.

[42] These 8.7 million tonnes of CO_2 are equivalent to Cambodia's annual CO_2 emissions from energy use (WRI 2018).

A set of sensitivity analysis has been performed for each of the four solar PV sub-sectors, with the objective to gain a better understanding of the robustness of the modelling outputs. Sensitivity analysis on key input assumptions[43] and on the impact of carbon pricing on the baseline energy scenario illustrated that generation costs are sensitive to key assumptions.

For example, when assuming an optimistic scenario in which favorable conditions for rooftop PV occur simultaneously, a generation cost as low as USD 5 cent can be achieved in Cambodia. Please see individual solar PV sub-sector chapters for detailed results of the sensitivity analysis.

In addition, an initial cost-benefit analysis[44] on different solar import tax exemption scenarios illustrates that significant net-benefits can be achieved over investment lifetimes in all four solar PV sub-sectors, especially where initial investments costs per MW are high, and where the use of batteries for electricity storage represents a large share of overall costs. Across all four sub-sectors, an approach where Cambodia waives VAT and import duties on hardware can create total net benefits of USD 35 million in economic savings. Further details on the sensitivity sections are found in Chapter 5 (utility-scale PV), Chapter 6 (rooftop PV), Chapter 7 (solar-battery MG) and Chapter 8 (SHS).

Next Steps

In order to build consensus and political action, the analysis and findings in this report can be further discussed and developed among key stakeholders. The intent of this report is not to provide a predominant result, but to provide transparent findings, inputs and assumptions, so that they can contribute to an informed design process.

The report furthermore identifies a number of possible follow-up modelling and research steps to deepen the technical analysis.

Should Cambodia wish to advance immediately with solar PV, then Cambodia can proceed with the following for each of the four sub-sectors:

- *Comprehensive approach:* implement the package of public derisking measures;
- *Focused approach:* implement certain priority derisking measures only.

Such actions can be guided by an implementation road map and in coordination among ministries, and with international partners and donors.

[43] Analyzed input assumptions include investment costs, solar capacity factor, financing costs and lease term (for SHS only).

[44] Costs and benefits are calculated over the investment lifetime of the asset. Costs represent foregone revenue for the government for not-collected import taxes on solar equipment; benefits represent the reduction of generation costs due to the tax exemption. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that the reduction in electricity generation costs is higher than the potential revenue from import taxes, making import tax exemption on solar PV equipment an economically viable instrument.

Chapter 1 | Introduction

Introduction

1

The analysis set out in this report forms part of the United Nations Development Programme's (UNDP) support to the Kingdom of Cambodia to support private sector investment in on- and off-grid solar photovoltaic (PV) renewable energy (RE) in the country.

This report focuses on the application of UNDP's 'Derisking Renewable Energy Investment' methodology to on- and off-grid solar PV investments, targeting the solar PV sub-sectors utility-scale PV, solar PV, solar-battery mini-grids (solar-battery MG), as well as solar home systems (SHS). By systematically assessing the impact of investment risks alongside a menu of public derisking measures for each solar PV sub-sector, the main objective of this report is to contribute to creating an enabling environment for solar photovoltaic energy.

In doing so, the report also aims to enhance UNDP's collaboration with other international development organizations that currently are on the ground, working towards catalyzing solar PV and other RE investments.

Chapter 2

Overview of the Derisking Renewable Energy (RE) Investment (DREI) Methodology

Overview of the Derisking Renewable Energy (RE) Investment (DREI) Methodology

2

In 2013, UNDP issued the 'Derisking Renewable Energy Investment report' (the 'DREI report') (UNDP, 2013)[45]. The report introduced an innovative framework, with an accompanying methodology (the "DREI methodology") and financial tool in Microsoft Excel, to quantitatively compare different public instruments for promoting RE investment.

This section provides an overview of the following aspects of the DREI methodology:

- the framework's focus on financing costs for RE investment;
- the framework's approach to identifying a public instrument mix;
- the methodology's four-stage structure.

For more detailed information on the DREI framework, please see the 2013 DREI report.

2.1 The impact of high financing costs on renewable energy

A key focus of the DREI framework is on financing costs for RE. While technology costs for RE have fallen dramatically in recent years[46], private sector RE investors in developing countries still face high financing costs (both for equity and debt). These high financing costs reflect a range of technical, regulatory, financial and informational barriers, and their associated investment risks. Investors in early-stage RE markets, such as those of many developing countries, require a high rate of return to compensate for these risks.

Figure 2, based on the 2013 DREI report, illustrates how these high financing costs can impact the competitiveness of RE. The figure illustrates the results of UNDP modelling to compare the levelized cost of electricity (LCOE)[47] of utility-scale onshore wind energy and combined-cycle gas in a low, and high financing cost environment. The illustrative analysis assumes a cost of equity of 7% and a cost of debt of 3% in the low financing cost environment, and a cost of equity of 16% and a cost of debt of 8% in the high financing cost environment. All modelling assumptions (investment costs, operational costs, capacity factors) are kept constant between the two environments – the only assumption that is varied is that relating to financing costs.

In a country benefiting from low financing costs, wind power (at USD 6.2 cents per kWh) could almost be cost-competitive with gas (at USD 6.3 cents per kWh). However, in a country with higher financing costs, wind power generation (at USD 9.2 cents per kWh) becomes 49% more expensive than in a country with

[45] Available for download at www.undp.org/DREI.

[46] For example, in the case of solar photovoltaic, according to data from Bloomberg New Energy Finance, module costs experienced a 99 percent reduction between 1977 and 2013 (WEC, 2013). More recently, between 2010 and 2016, module costs declined 80%, according to IRENA data (IRENA, 2018).

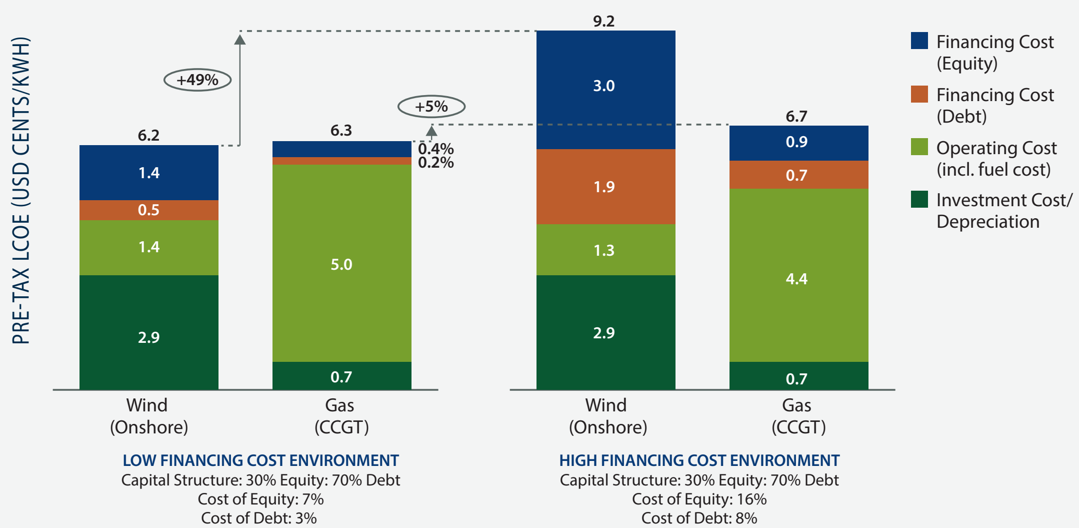
[47] The Levelized Cost of Energy (LCOE) is a measure which allows for comparison of cost competitiveness of power-generating systems. It is an economic assessment of the average total cost to build and operate a power-generating asset over its lifetime divided by the total energy output of the asset over that lifetime. The LCOE can also be regarded as the average minimum price at which electricity must be sold in order to break-even over the lifetime of the project. It does not present the electricity tariff which will account for additional cost factors such as the IPPs internal cost structure, profit margin, externalities and others. The LCOE is typically expressed in present dollars per energy unit, using net present value principles, i.e. future expenses and income are discounted by the yearly cost of financing.

low financing costs. In contrast, gas (at USD 6.7 cents per kWh) becomes only 5% more expensive due to these same higher financing costs. Therefore, in the country with high financing costs, wind power is no longer competitive with gas.

The sensitivity of wind power – and many other forms of RE (Schmidt, 2014) – to financing costs is due to the high upfront capital intensity of renewable energy. RE's upfront capital intensity is a function of its required initial investment in equipment, for example, wind turbines and solar panels. Following this initial investment, RE typically has very low operating costs and does not require any fuel costs. Fossil fuel-based energy generation typically has the reverse profile, with relatively low upfront costs, high operating costs and fuel costs[48]. The end result is that high financing cost environments penalize RE when compared to fossil-fuel based power generation.

The theory of change underlying the DREI methodology is one of the main challenges for scaling-up RE technologies in countries with high financing costs, is to lower the financing costs that affect renewables' competitiveness against fossil fuels. Because these higher financing costs reflect barriers and associated risks in the investment environment, the key entry point for policy-makers promoting RE is to address these risks and therefore lower overall life-cycle costs.

Figure 2: Comparing utility-scale wind energy and gas LCOEs in low and high financing cost environments



Source: Derisking Renewable Energy Investment (UNDP, 2013), subsequently updated as of 2017.

All assumptions besides the financing costs are kept constant between the low and high financing cost environments. Wind energy technology assumptions: investment cost: 1,520,000 USD/MW, O&M: 31,600 USD/MW/year, capacity factor: 30%, annual inflation: 2%; Gas (Combined cycle gas turbine (CCGT) assumptions: investment cost: 910,000 USD/MW, O&M: 35,100 USD/MW/year, full load hours: 5,000/year, fuel efficiency: 58%, annual Inflation: 2%; fuel costs are projected using the International Energy Agency's (IEA) New Policies Scenario, based on 2016 EU Import Prices for Natural Gas as the starting point. For more detail on data sources, please refer to Annex B.

Operating costs appear as a lower contribution to LCOE in developing countries due to discounting effects from higher financing costs.

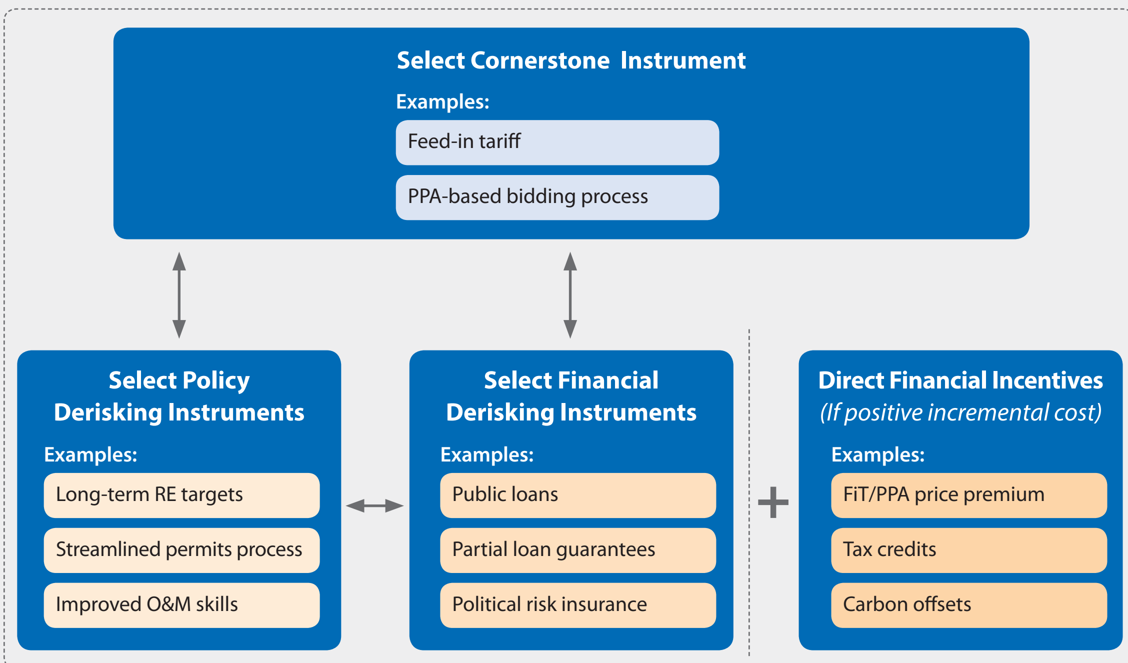
[48] For example, based on the analysis shown in Figure 2, investment costs account for approximately 80% of the total lifetime technology costs for wind energy but only account for around 20% of such costs in the case of gas. See Annex A of the DREI report for assumptions.

2.2 Identifying a public instrument mix to support renewable energy (RE)

In seeking to create an enabling investment environment for RE, policy-makers typically implement a package of public instruments. Identifying an appropriate combination of instruments can be highly challenging. Moreover, these public instruments can come at a cost – to industry, to consumers or to the taxpayer.

From a financial perspective, the overall aim for policy-makers in assembling a public instrument package is to achieve a risk-return profile for RE that can cost-effectively attract private sector capital. *Figure 3*, from the DREI report, identifies the four key components of a public instrument package that can address this risk-return profile.

Figure 3: Typical components of a public instrument package for utility-scale renewable energy



Source: Derisking Renewable Energy Investment (UNDP, 2013).

The **cornerstone instrument** is the centerpiece of any public instrument package. While there are tens, if not hundreds, of public instruments, only a select handful of instruments have shown themselves to be highly effective at transforming markets. For utility-scale RE, the cornerstone instrument is typically a Feed-in Tariff (FiT), auction mechanisms or a Power Purchase Agreement (PPA) tender process, either of which allows independent power producers (IPPs) to enter into long term (e.g. 15-20 year) power purchase agreements with grid operators.

Three core types of public instruments can then complement the cornerstone instrument:

- **Instruments that reduce risk**, by addressing the underlying barriers that are the root causes of investment risks. These instruments utilize policy and programmatic interventions. An example might involve a lack of transparency or uncertainty regarding the technical requirements for RE project developers to connect to the grid. The implementation of a transparent and well-formulated grid code can address this barrier, reducing risk. The DREI methodology terms this type of instrument "**policy derisking**".

- **Instruments that transfer risk**, by shifting risk from the private sector to the public sector. These instruments do not seek to directly address the underlying barrier but, instead, function by transferring investment risks to public actors, such as development banks. These instruments can include credit lines, public loans and guarantees, political risk insurance and public equity co-investments. For example, the credit-worthiness of a PPA may often be a concern to lenders. A development bank guarantee can provide banks with the security to lend to project developers. The DREI methodology terms this type of instrument "**financial derisking**".

- **Instruments that compensate for risk**, by providing a financial incentive to investors in the RE project. When risks cannot be reduced or transferred, residual risks and costs can be compensated for. These instruments can take many forms, including price premiums (either as part of a PPA or FiT), tax breaks and proceeds from the sale of carbon credits. The DREI methodology calls these types of instruments "**direct financial incentives**".

2.3 The methodology's four-stage structure

The DREI report sets out a detailed methodology, together with a financial tool in Microsoft Excel, to support policy decision-making by quantitatively comparing different public instrument portfolios and their impacts.

The selection of public instruments for RE is highly dependent on national circumstances. Each country has its own particular renewable resources, objectives and constraints. Therefore, the methodology is designed to be applied flexibly and to be tailored to a specific RE technology, and national context. As illustrated in *Figure 4*, the methodology is organized into a framework with four stages, each of which is, in turn, divided into two steps.

- **Stage 1: Risk Environment.** Identifies the set of investment barriers and associated risks relevant to the RE technology, and analysis how the existence of investment risks can increase financing costs.

- **Stage 2: Public Instruments.** Selects a mix of public derisking instruments to address the investor risks and quantifies how they, in turn, can reduce financing costs. This stage also determines the cost of the selected public derisking instruments.

- **Stage 3: Levelized Cost.** Determines the degree to which the reduced financing costs impact the RE life-cycle cost (LCOE). This is then compared against the current baseline generation costs in the country.

- **Stage 4: Evaluation.** Assesses the selected public derisking instrument mix using four performance metrics, as well as through the use of sensitivity analysis. The four metrics are: (i) investment leverage ratio; (ii) savings leverage ratio; (iii) end-user affordability and; (iv) carbon abatement.

The intent of the methodology is not to provide one predominant numerical result but is, instead, to facilitate a structured and transparent process whereby key inputs and assumptions are made explicit, so that they can contribute to and inform the design process.

Figure 4: Overview of the DREI methodology for selecting public instruments to support renewable energy investment

	Step 1		Step 2
Stage 1: Risk Environment	• Determine a multi-stakeholder barrier and risk table for the renewable energy investment	→	• Quantify the impact of risk categories on increased financing costs
Stage 2: Public Instruments	• Select one or more public derisking instrument(s) to mitigate the identified risk categories	→	• Quantify the impact of the public derisking instrument(s) to reduce financing costs • Quantify the public costs of the public derisking instrument(s)
Stage 3: Levelised Cost	• Calculate the levelised cost of electricity (LCOE) for the baseline energy generation mix in the particular country	→	• Quantify the LCOE for renewable energy investment in the (i) pre-derisking and (ii) *post*-derisking scenarios • Calculate the incremental cost (or savings) by comparing these scenarios vs. the baseline
Stage 4: Evaluation	• Analyse the selected public instrument(s) in terms of four key performance metrics	→	• Perform sensitivity analyses on key inputs and assumptions

Source: Derisking Renewable Energy Investment (UNDP, 2013).

Chapter 3

Current Status of Solar PV in Cambodia

Current Status of Solar PV in Cambodia

3

This section provides a brief overview of the current context, status and objectives for solar PV in Cambodia.

General Country Data[49]	
Population 2017:	16.2 million
Land Area:	181,035 sq. km
GDP 2017 (USD):	$64.2 billion
GDP/capita (USD) 2017:	$4,000
Sovereign rating 2018:	B2 stable (Moody's)
UNDP HDI 2017	0.563 (143rd of 188)
World Bank Ease of Doing Business (2018):	135th of 190

Targets for Solar PV

There are currently no official targets for solar PV in Cambodia. Hence, this report uses illustrative long term and private sector investment targets for solar PV in Cambodia. For on-grid solar PV, the illustrative investment target is set at 700 MW[50] by 2030, split equally between utility-scale PV and rooftop PV. The investment target for rooftop PV is further equally split between the commercial and industrial (C&I)[51], and the residential sector.

For off-grid electrification, the government aims to provide basic electricity access to all villages by 2020 and grid-quality electricity access to 90% of all households by 2030 (MME, 2018). For off-grid solar PV, the report uses illustrative block targets of 10 MW[52] by 2025[53]. For solar-battery MG, one 10 MW block target equates to 490 systems each sized at 20.4 kWp and serving 100 households. This means that one 10 MW solar-battery MG building block serves 49,000 households and 231,000 people. For solar home systems, the same illustrative target equates to the electrification of 100,000 households, or 470,000 people with each SHS sized at 100 Wp.

On-Grid Power

Cambodia's on-grid power sector is characterized by rising electricity demand, with annual demand projected to increase by 15-20% up to 2020 and beyond. Cambodia's power market is liberalized with IPPs significantly embedded in the country's power generation landscape. National power distribution is mainly provided by Electricité Du Cambodge (EDC), with Rural Electricity Enterprises (REEs) providing distribution services for the last mile.

Cambodia has approximately 2,300 MW in power generation capacity (EAC, 2018)[54]. As set out in *Figure 5* the baseline energy mix is dominated by coal and hydro, accounting for over 95% of domestic generation. Solar PV and biomass contribute only marginally to the country's power generation. In addition, Cambodia imports 22% of its overall energy from neighboring countries, particularly during the dry season from December to April (EDC, 2015).

[49] Sources: EIU (2018); World Bank (2018); UNDP (2017); Moody's (2018), Climate Investment Fund (2017); UNFCCC (2017)

[50] The overall target of 700 MW equates to approximately 20% of anticipated 2030 total installed capacity in Cambodia (IRENA, 2016). The feasibility of the illustrative Solar PV investment targets used in this study have been confirmed by EAC and local solar PV project developers.

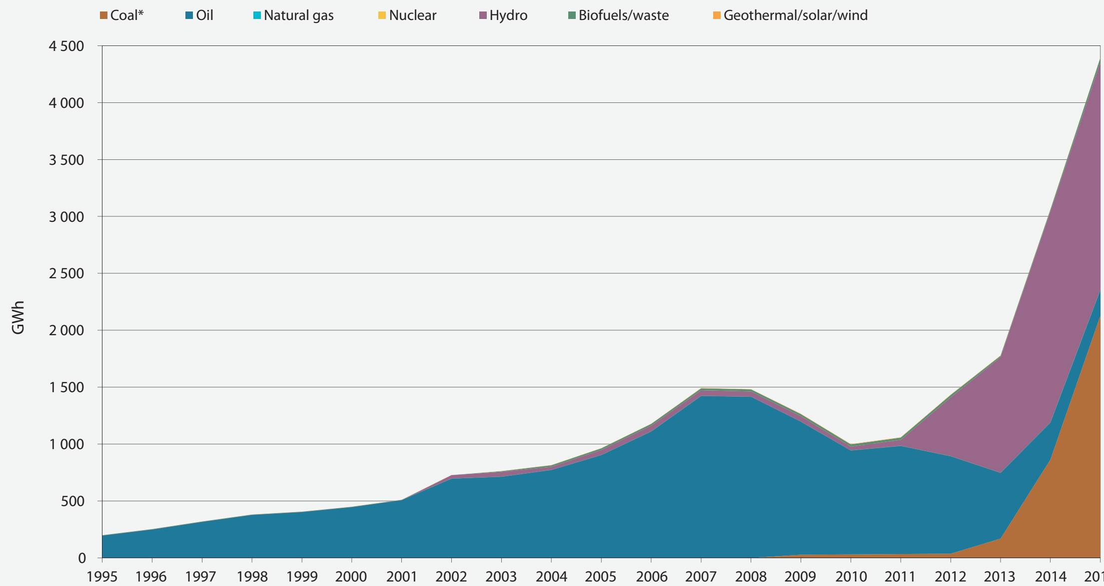
[51] In the DREI exercise, modelling is solely performed on rooftop PV for the C&I sector, with a 2030 investment target of 175 MW. Modelling on the residential sector has not been performed.

[52] 10 MW building blocks targets can be multiplied.

[53] The shorter investment framework for off-grid solar PV (2025 opposed to 2030) is due to the immaturity of off-grid technologies and business models, which are anticipated to evolve and change faster than mature and proven on-grid solar PV approaches.

[54] Analyzed input assumptions include investment costs, solar capacity factor, financing costs and lease term (for SHS only). Includes power generation capacity from electricity imports from neighboring countries. Cambodia's national installed generation capacity in 2017 was 1,900 MW.

Figure 5: Electricity generation by fuel in Cambodia (1995 to 2015)



* In this graph, peat and oil shale are aggregated with coal, when relevant.

Source: OECD/IEA (2017).

Electricity retail tariffs in Cambodia are among the highest in Southeast Asia, ranging from USD 9.5 to USD18.25 depending on voltage and type of customers[55]. The average electricity consumption per capita is estimated at 55 kWh/month; with urban households consuming significantly more electricity (128 kWh/month) than households in rural areas (38 kWh/month) (World Bank, 2018).

Off-Grid Electrification

Cambodia has made rapid progress in increasing access to electricity for villages, households and other consumers. 97.6% of Cambodian households have access to at least once source of electricity, with 71.5% having access to grid electricity and 26.1% to off-grid electricity. 88.2% of households have access to at least 4 hours of electricity supply a day (Tier 1-5)[56], but only 13% have access to at least 23 hours of supply a day with adequate reliability, quality, affordability, and health and safety (Tier 5). Most non-grid connected households either use rechargeable car batteries charged at village charging stations, or self-owned, basic SHS systems, which can power low-load appliance such as a television or fan. Very few households use solar lanterns or solar lighting system, which typically provides only lighting and phone charging (World Bank, 2018).

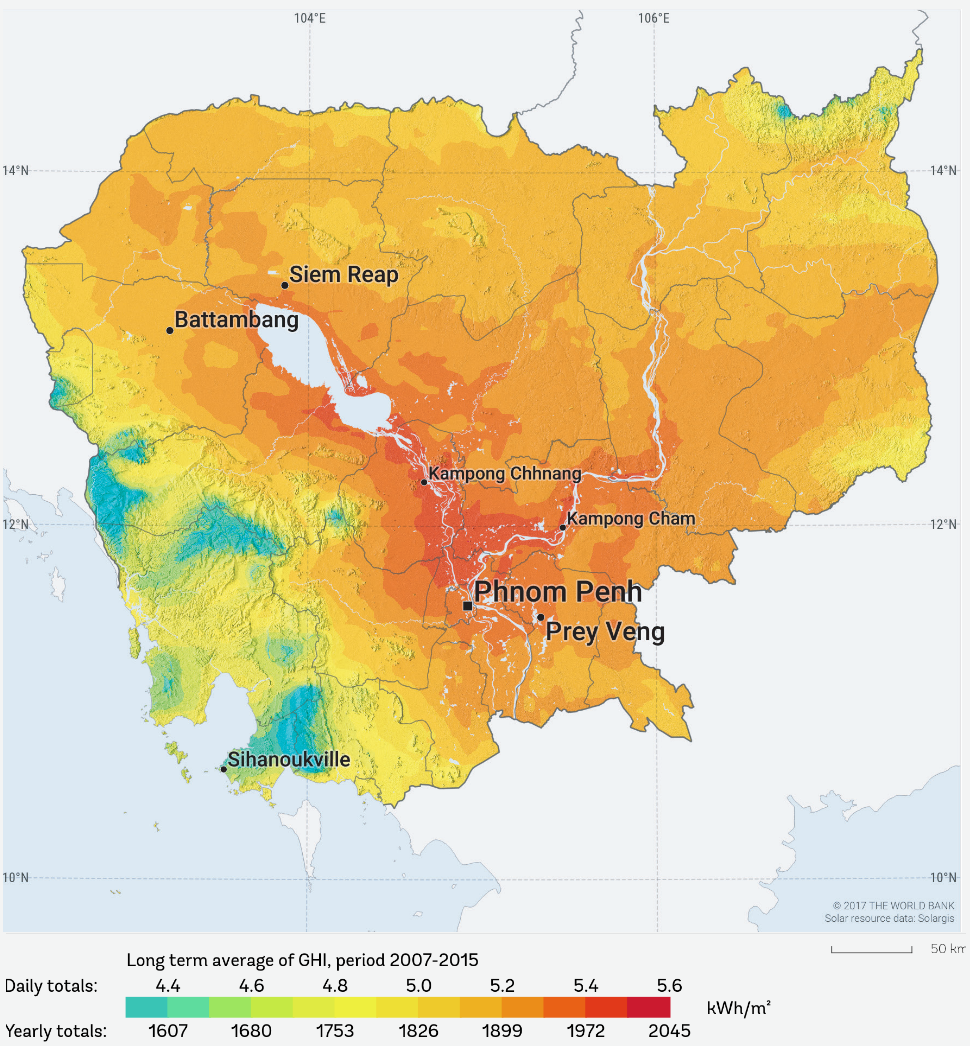
[55] During finalization of this report in December 2018, the Government of Cambodia has announced to accelerate the national electricity reduction plan 2019-2020, effectively reducing the electricity retail tariffs for different consumer groups. Furthermore, EAC and MME have been advised to look into further electricity tariff reductions starting in 2021. The tariff reduction will be financed through a USD 50 million government subsidy to the electricity sector. For details about electricity tariffs, see annex B.

[56] Tier levels are in reference to World Bank's Multi-Tier Framework (MTF) approach, which measures energy access on several attributes that capture key characteristics of the energy supply including availability, affordability, reliability, quality, formality, and health and safety. Based on those attributes, the MTF defines six tiers of access, ranging from Tier 0 (no access) to Tier 5 (full access). See World Bank's 2018 Multi-Tier Framework report on Cambodia for further details on the methodology and analysis results.

Solar Energy Resources

Cambodia has abundant solar resources and high solar potential with an average of 5 kWh/m²/day and an average sunshine duration of 6-9 hours per day. Solar irradiation is strongest in the middle and south west of Cambodia. The technical solar potential has been estimated at 8,100 MW, yielding an energy output of approximately 15,000 GWh/year (SEAC; ADB, 2016). *Figure 6* illustrates the solar resource map for Cambodia.

Figure 6: Resource map for solar energy in Cambodia



Source: World Bank (2017); Source -Solar Data: Solargis (2017).

Current Status of Solar PV Investment

There is strong interest from domestic and international private sector investors and developers in solar PV in Cambodia. However, investment levels to date have been low.

Cambodia's first and only utility-scale solar farm, the Bavet Solar Farm with 10 MW capacity and an estimated investment volume of USD 12.5 million, went operational in 2017. In the same year, Global Purify Power (GPP), a Phnom Penh-based developer backed by a group of Southeast Asian investors, has started building the first 15 MW phase of a planned 225 MW solar rollout in Cambodia. A 100 MW national solar park program by EDC, backed by the Asian Development Banke (ADB), is being developed, including a 30 MW facility planned to start operations by 2020[57]. Additionally, a collaboration between Jinko Solar and SchneiTec Group started the development of a 60 MW solar farm in October 2018 with an expected completion and commercial operation date set for December 2019. The government's target for utility-scale PV by 2020 amounts to 130 MW. In the rooftop PV space, a small number of purely captive systems[58] exist, including internationally supported systems such as the country's largest rooftop PV installation to date, Coca Cola's 2.6 MW rooftop PV plant, the PV plant at the International School of Phnom Penh (1 MW), and a few other systems in the C&I and residential sector. Overall, the rooftop PV market is still small. A new regulation on the integration of rooftop PV sources to the national grid was issued in February 2018, but its long-term impact on rooftop PV investments remains to be seen, with some developers citing unsecure financial viability of smaller projects under the new regulations[59].

Similarly, off-grid solar PV investment is very limited and has mainly been driven by public programs. There are currently no solar-battery MGs in operation at the village level, which rely on diesel gensets – often in combination with rechargeable car batteries – to bring electricity to individual households. Solar home systems have been supported through initiatives such as the Rural Electrification Fund (REF)[60] and the Green Microfinance Program[61], and although half of 26% of households with electricity access through off-grid solutions are using SHS, the systems are basic in nature. Higher capacity solar home systems using digital payment solutions and promoting energy efficiency appliances, as envisaged in this DREI modelling, have not yet been supported or marketed.

Several international actors are engaged in advancing the solar PV market in Cambodia. See *Table 5* for an overview of current international support to solar energy in the country.

[57] According to ADB, individual solar plants of this planned solar farm will be tendered out to private developers in smaller phases. The solar park is a Public Private Partnership (PPP) in which the government purchases and owns the land.

[58] A captive rooftop PV system utilizes all of the generated electricity for its own use without feeding electricity to an external grid.

[59] The new regulation aims to clarify the general conditions for installing and operating solar PV systems in Cambodia. In general, consumers can install solar PV systems for their own consumption, as long as these systems do not require connection and synchronization with the National Grid. Big Consumers (medium voltage consumers) and Bulk Consumers (high voltage consumers) may consume electricity generated from their installed solar PV and also be synchronized with the National Grid. For these consumers, a two-part tariff system applies comprising a capacity charge and a solar tariff. The capacity charge and solar tariff depends on the connection with the main grid (high voltage, medium voltage, etc.)

[60] The REF is managed by the World Bank (2004-2012), GEF, KfW and the Cambodian Government, and provide grants and loans for technical assistance, project finance and operations for mini/micro hydro, biomass and solar PV.

[61] The Green Microfinance Programme, managed by AFD, EU and SNV, assists villagers to take out loans to purchase solar energy systems and helps build the capacity of local technicians to install the solar panels and small business entrepreneurs to retail them.

Table 5: International support to solar energy in Cambodia

ORGANIZATION	SUMMARY OF ACTIVITIES
ADB	10 MW Bavet Solar Farm; 100 MW national part; Scaling-up Renewable Energy Program (SREP); transaction advisory services for competitive tender; technical study on grid integration and solar PV road map
AFD, EU, SNV	Green Microfinance Programme; Good Solar Initiative certification program for solar PV
GGGI	Solar city concept in cooperation with MME, EDC and NCSD
IFAD	Support to small farmers through Scaling-Up of Renewable Energy Technologies (S-RET) GEF project
Investing in Infrastructure (3I)	Financial and technical support to RE policy development, including low voltage connections of solar PV
UNDP	Derisking investment in solar PV; solar pumping market assessment study
USAID	Clean Power Asia, policy support to MME
World Bank/KFW	Support to the Rural Electrification Fund (REF), including SHS rollout
World Bank	Energy access analysis based on the Multi-Tier Framework
WWF	Study on sustainable energy use and alternatives for power generation in Cambodia[62]

Key Institutions in Cambodia's Electricity and Climate Change Context

Ministry of Mines and Energy (through the General Department of Energy (GDE) is the main government agency responsible for energy policy formulation, strategic energy planning, development of technical standards for the power sector, as well as some energy data.

Electricity Authority of Cambodia (EAC): EAC serves as the national electricity regulator for Cambodia's electricity businesses, setting and administering licensing, tariff setting, settling of disputes between producers or suppliers and consumers, accounting standards, enforcement of regulations, and review of performance.

Electricité Du Cambodge (EDC): EDC is a state-owned and vertically integrated organization responsible for generation, transmission, and distribution. It is owned jointly by the MME and the Ministry of Economy and Finance.

The National Council for Sustainable Development (NCSD): NCSD – established in May 2015 as successor of the National Climate Change committee (NCCC) – is a cross-sectoral and multi-disciplinary body with the mandate to prepare, coordinate and monitor the implementation of policies, strategies, legal instruments, plans and programs related to climate change in Cambodia. NCSD aims to improve the coordination of climate change activities in Cambodia and to support a stronger, comprehensive and effective climate change response.

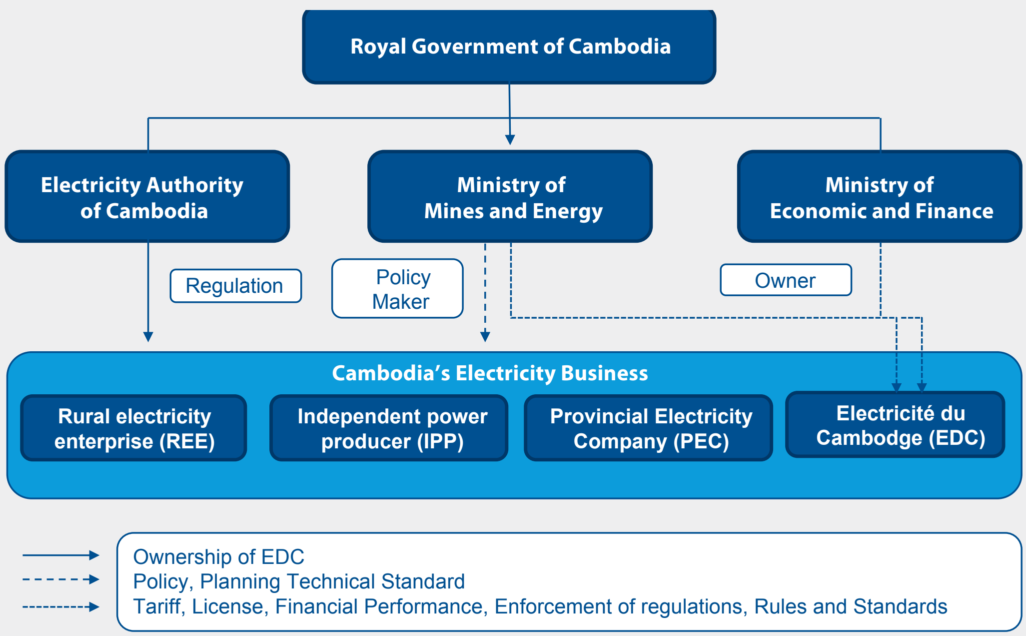
[62] WWF Cambodia Renewable Energy Report 2016.

Rural Electricity Enterprise (REE): REEs are privately-owned, licensed electricity providers selling power into local distribution networks. Although REEs sometimes have their own generation assets (typically diesel), REEs currently provide mostly electricity distribution services.

Provincial Electricity Company (PEC): PECs traditionally operate as integrated utilities at the province and sub-province level and have mostly been replaced by REEs and IPPs.

An overview of the key actors in Cambodia's electricity sector is provided in *Figure 7*.

Figure 7: Structure and key actors of Cambodia's electricity sector



Source: Government of Cambodia (2016), ADB (2016).

Chapter 4

Modelling of Solar PV Investments in Cambodia

Modelling of Solar PV Investments in Cambodia

4

This section describes the DREI modelling for promotion of private sector investment in on-grid and off-grid PV in Cambodia. A summary of the approach to the modelling is provided, which describes the two scenarios modelled and highlights key modelling assumptions.

As in any modelling exercise, the modelling uses a set of underlying data and assumptions that are presented in Annex A. Further in-depth data collection can strengthen the robustness of these results.

4.1 The Model's Approach

4.1.1 Modelling Two Core Scenarios in Cambodia

In order to study different public instrument packages, the modelling compares two core scenarios to achieve the envisioned on- and off-grid solar PV investment targets: a business-as-usual (BAU) or pre-derisking scenario and a post-derisking scenario. Both scenarios take today's prevailing (2018[63]) risk environment in Cambodia as the starting point. For utility-scale and rooftop PV, the period for the financial modelling is set from 2019 to 2030 (12 years), while for solar-battery MG and SHS a slightly shorter period from 2019 to 2025 (7 years) is applied.

- **Business-as-usual (BAU) scenario**
  - This scenario assumes that the envisioned 2030 on-grid and the 2025 off-grid investment targets are achieved under today's risk environment in Cambodia.
  - The BAU scenario uses the current financing costs and terms (capital structure) that an investor encounters in Cambodia.
- **Post-derisking scenario**
  - This scenario assumes that the envisioned investments targets are achieved under a de-risked investment environment, in which a set of policy derisking and financial derisking instruments are deployed to address current investment risks and associated barriers.
  - The post-derisking scenario uses adjusted financing costs and terms (capital structure) compared to the BAU scenario, reflecting the impact of derisking instruments in reducing the financing costs and improving financing terms.

4.1.2 Key Modelling Assumptions

The application of the DREI methodology entails a significant amount of data gathering and requires a number of assumptions to be made. In order to keep the scope of the modelling manageable, sets of simplified data and modelling assumptions for both on- and off-grid solar PV have been used.

[63] Data collection has been performed between September 2017 and July 2018.

The following key assumptions for on- and off-grid solar PV are guiding the modelling:

- **On-grid Solar PV**
  - **Business Model**
    - For utility-scale PV, the report assumes a build-own-operate business model with project finance and a typical power plant size of 30-100 MW.
    - For rooftop PV, the modelling assumes a third-party ownership business model (leasing to end-users) with rooftop PV systems sized between 200 kWp and 2 MWp, and without battery storage.
  - **Baseline approach**
    - On-grid solar PV investments are made in the context of an existing or evolving (with new installed capacity coming online) electricity generation mix. The model assumes that Cambodia, in its BAU scenario will continue to add super-critical coal[64] and large hydro power plants as main means to increase its electricity generation capacity in the future[65]. The baseline technology mix therefore assumes a marginal baseline approach of 50% coal (supercritical) and 50% large hydro.
    - Cambodia is assumed to have considerable natural gas resources in the Gulf of Thailand, but gas does not contribute to the current national electricity mix. The government has expressed the intention to introduce gas into the electricity mix as of 2024, but no concrete implementation strategy exist as of today, and therefore, natural gas has not been considered in the future baseline mix.
    - The modelling assumes a combined baseline grid emission factor equating to 0.458 tonnes of CO_2e/MWh.
    - Limitations: the baseline only reflects generation costs and does neither include transmission and distribution costs nor transmission losses. Furthermore, the baseline generation calculation is sensitive to technology choice assumptions and does not reflect externalities including carbon pricing, water pollution and fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health.
  - **Variability.** An inherent characteristic of solar PV is its variability and lack of dispatchability. Energy planners often need to balance solar PV (and other intermittent RE technologies) with dispatchable capacity, LCOE-based comparisons using variable energy sources could have limitations by not capturing this balancing cost or generation costs at peak demand. The modelling does not include balancing costs. The assumed targets for on-grid solar PV for 2030, equating approximately 20% of anticipated 2030 total installed power generation capacity in Cambodia, are expected to be absorbed into Cambodia's power grid with minimal cost or disruption[66].

[64] A supercritical coal power plant is the current standard for new coal power plants. It operates with an efficiency rate of around 44%, compared to 33% reached by older coal power plants. The most efficient coal-fired power plant type currently in operation is the ultra-critical coal power plant which can reach efficiency factors of up to 50% (Energy Education, 2018).

[65] This assumption is based on the publicly available generation expansion plan (MIME and IRENA, 2016).

[66] The target of 350 MW each for solar rooftop PV and utility scale PV (total 700 MW) is not an official target set by the government of Cambodia, but an assumption from the authors based on international experiences and consultations with government and stakeholders. In addition, it does not imply that the current grid can technically absorb 700 MW of variable renewable energy (VRE) sources. It is an assumption to allow for carrying out the financial and economic modelling, assuming that the grid will gradually be upgraded over time allowing for a higher percentage of VRE to be added without affecting grid stability. The new power development plan that will be prepared in 2019 will officially determine the share of various renewable energy sources into the power grid.

- **Transmission Lines.** In order to keep the modelling manageable, the modelling assumes that all utility-scale PV sites are within 10 km of the existing grid. Rooftop PV installations are assumed to be in direct proximity to the existing grid. Capital costs related to the upgrade and maintenance of the grid infrastructure in Cambodia are excluded from the analysis.

- **Unsubsidised baseline fuel costs.** The modelling exercise uses unsubsidised fuel prices for coal. Coal prices are projected using the World Bank Commodities Price Forecast (Australia, constant USD[67]).

- **Investment costs for on-grid solar PV**
  - Globally, the costs of solar PV hardware have been decreasing consistently over time and are expected to continue to decrease
  - For utility-scale PV, this report assumes investment costs (i.e. solar modules[68], inverters and balance-of-system) at the mid-point 2024 of the modelling period 2019-2030. The cost estimates are derived from the latest projections elaborated by the International Renewable Energy Agency published in June 2016 (IRENA, 2016).
  - For rooftop PV, investment costs have been assumed based on feedback from local rooftop PV developers.
  - To complement this approach, the sensitivity analyzes illustrate the impact on the results when assuming higher or lower investment costs for utility-scale and rooftop PV.

- **Off-grid Solar PV**
  - **Business Model.**
    - For solar-battery MG, the report assumes a private sector, build-own-operate model, with each private sector developer aggregating multiple mini-grid sites. Each site assumes a generic mini-grid system size of 20 kWp solar modules and 60 kWh battery storage (lithium-ion), serving 100 households each.
    - For SHS, the modelling assumes generic 100 Wp SHS units including battery storage and a kit of energy efficient household appliances, with a pay-as-you-go (PAYG) mobile money system under a 3-year lease-to-own business model.
  - **Baseline approach.**
    - **Solar-battery MG**
      - For solar-battery MG, the baseline assumes the use of a demand-reflective diesel-based mini-grid. The demand has been modelled considering typical electrical appliances, power consumption rates and usage duration in rural areas in Cambodia. The electricity demand modelling estimates future electricity needs of three end-user types, namely individual households, productive use and community/social infrastructure.
      - The diesel-based mini-grid baseline reflects generation, transmission and distribution costs, as well as transmission losses. The baseline does not reflect externalities including carbon pricing, water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health.

[67] World Bank Commodities Price Forecast (2018).
[68] Crystalline silicon technologies

  - The modelling assumes a mini-grid baseline grid emission factor equating to 0.889 tonnes of CO_2e/MWh.

  - Initial solar-battery MGs are being installed or considered for installation in remote areas in Cambodia where the main grid will not reach in the near future (in line with the power development plan). Given the limited experiences, insufficient data is available on costs and performance etc. in a Cambodian context. As such data on performance and costs from other countries is used and adjusted to the Cambodian situation as per feedback from stakeholders. When more MGs have been installed, more data might become available.

- **SHS**
  - For SHS, the baseline assumes the use of diesel generators in village charging stations common in Cambodia. Households typically charge their rechargeable car batteries at these stations and use the battery for electricity. The electricity demand modelling for SHS estimates future electricity needs of households only and excludes productive use, and community/social infrastructure needs.
  - The modelling assumes a baseline grid emission factor equating to 0.889 tonnes of CO_2e/MWh.

- **Unsubsidised baseline fuel costs.** The modelling exercise uses unsubsidised fuel prices for diesel. Assumed diesel prices are reflecting current diesel prices in Cambodia adjusted to include fuel transportation costs.

- **Installed costs for off-grid solar PV.** For both solar-battery MG and SHS, investment costs for solar modules, batteries, inverters and balance of systems (BOS) have been assumed based on feedback from local solar PV developers.

The full underlying data sets and assumptions for the modelling are set out in Annex A.

Chapter 5

On-Grid – Utility-Scale PV Results

On-Grid – Utility-Scale PV Results

5

This chapter sets out the modelling results for utility-scale PV in Cambodia. The results present a set of cost-effective public derisking measures that allow meeting the study's investment targets for utility-scale PV of 350 MW by 2030. The results are organized in terms of the DREI methodology's four stages, as introduced in Chapter 2 of this report.

5.1 Risk Environment (Stage 1)

Interviews

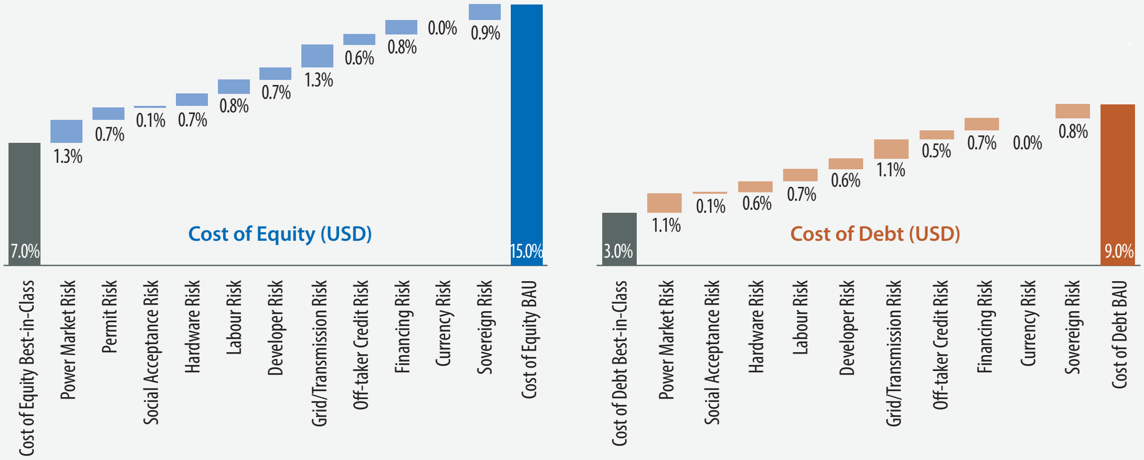
Data on the risk environment were obtained from 22 structured interviews held with domestic and international investors, and project developers who are considering or are actively involved in on- and off-grid solar PV opportunities in Cambodia and the Southeast Asian region. These investors reflect a variety of interests, both strategic and financial.

Financing Cost Waterfalls

The analysis of the contribution of investment risks to higher financing costs for utility-scale PV in Cambodia is illustrated in the financing cost waterfall in *Figure 8*.

Based on data from interviews focusing on the risk environment of utility-scale PV, the report estimates that financing costs for utility-scale PV today are 15% for the cost of equity (CoE), and 9% for the cost of debt (CoD)[69]. These are substantially higher than in the best-in-class country Germany, where the costs are estimated at 7% CoE and 3% CoD. In addition, investors are facing less attractive capital structures (debt to equity ratios). Given the longevity as well as the capital intensity of utility-scale PV, the impact of Cambodia's higher financing costs on the competitiveness of utility-scale PV with coal and hydro, and the country's dominating power generation technologies, is significant.

Figure 8: Impact of risk categories on financing costs for utility-scale PV investments in Cambodia, business-as-usual scenario (BAU)



Source: interviews with utility-scale PV investors and developers; modelling; best-in-class country for utility-scale PV is assumed to be Germany; see Annex A for details of assumptions and methodology.

[69] USD-denominated cost of equity and debt.

Cambodia's higher financing costs reflect a range of investment risks for utility-scale PV investments. The risk categories with the largest impact on elevated financing costs are (i) *power market risk*, related to uncertainty in the outlook and official targets for utility-scale PV, and absence of a standardized tendering process; and (ii) *grid/transmission risk*, arising from the lack of clarity on Cambodia's grid absorption capacity for RE and transmission line planning.

During the interviews, investors and project developers further provided qualitative feedback on the risk environment for utility-scale solar PV in Cambodia. A summary is provided in *Table 6*.

Table 6: Qualitative investor feedback on risk categories for utility-scale PV investment in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Power Market Risk	This risk category has a high impact on financing costs. Investors shared their concern about uncertainty in the outlook and targets for RE (especially the lack of specific capacity targets for solar PV), and changes in the supporting mechanisms. Investors also commented that the utility-scale market has just started with only one 10 MW solar farm starting operation in October 2017, and that missing experience adds to the uncertainty. Small RE developers are concerned by some of the big projects such as the planned ADB 100 MW solar farm project which could already take up much of the grid's anticipated absorption rate for RE. A FiT has previously been discussed with the government but has not received strong support at that time. Investors communicated that a bidding process is considered a preferred approach for utility-scale solar in Cambodia. Investors believe that two of EDC's main concerns include: (i) how to manage intermittent solar PV to the grid; and (ii) how solar PV would impact signed agreements with coal and hydro companies (take-or-pay contract) as RE supply may exceed demand, leading to stranded assets and/or contract defaults with coal and hydro companies.
Permit Risk	This risk category has a medium impact on financing costs. Investors mentioned that when winning an official tender for a utility-scale PV generation concession, the chance to receive required permits is assumed very likely. Investors also commented that a national partner is de facto required to win a tender. Without a tender, it is very difficult to receive any permits. The permitting system is still in its early days and permits risks may decrease if a systematic bidding process is introduced (potential time constraints for securing the permits). Investors identified land allocation as a potential permitting issue in the future when the development of solar farms picks up.
Social Acceptance Risk	This risk category has a low impact on financing costs. Most investors and project developers shared the view that this is a low risk. People need electricity and if a solar farm would enhance access to electricity and add to grid stability, people would welcome such investments.
Hardware Risk	This risk category has a medium impact on financing costs. Most investors assessed the risk of underperforming as low risk as the hardware provider or EPC contractor usually guarantees performance. However, frequent problems during custom clearing were mentioned by interviewees and pose a significant risk, especially due to potential solar farm downtime.
Labor Risk	This risk category has a medium impact on financing costs. Investors pointed out that experience from the Bavet solar farm project illustrated the difficulty to find skilled labor for a solar farm installation and that additional training was necessary. Investors and project developers agreed that finding skilled labor in the solar PV sector in general, and especially in rural areas, is currently difficult.
Developer Risk	This risk category has a medium impact on financing costs. Interviewees shared the view that there is currently only a very small number of reputable solar PV project developers in the country and that access to detailed information on available project developers and track records is challenging. The infancy of the utility-scale PV sector was mentioned as the main underlying cause.
Grid/Transmission Risk	This risk category has a high impact on financing costs. Investors identified the lack of a grid code standard as a key risk in this category. Furthermore, there is concern in regard to the potential absorption rate of the grid, which increases the investment uncertainty for investors.
Off-taker Credit Risk	This risk category has a medium impact on financing costs. Most interviewees agreed that EDC is a reliable off-taker and is generally considered to be in good financial health.
Financing Risk	This risk category has a medium impact on financing costs. Investors shared the view that although several professional domestic financial institutions with considerable assets exists, it is currently very difficult to access local debt finance, and that local financial institutions are not aware of solar PV opportunities and lack the capacity to properly evaluate risk and set up financial plans. All investments are coming from international sources. The main challenge for investors is to find bankable projects with an acceptable overall risk profile.
Currency Risk	This risk category has a low impact on financing costs. All investors agreed that the currency risk is not very high due the fact that the Cambodian Riel is pegged to the USD, and that most loans and payments are conducted in USD. The risk would be scored higher if the Cambodian government would unpeg the Cambodian Riel from the USD, but this is assumed very unlikely.
Sovereign Risk	This risk category has a medium impact on financing costs. All interviewees agreed that Cambodia has promising economic and social development prospects. Some interviewees expressed their concern about international relations, based on foreign news. Investors also agreed that it is difficult for foreign investors to judge this risk reliably and they are therefore often rather concerned about it. Domestic investors in contrast are usually better informed and are, to some extent, involved in governmental high-level discussions and feel more comfortable to predict sovereign-related risks.

5.2 Public instruments (Stage 2)

Selection and costing of public instruments

Having identified the key investment risks for utility-scale PV, a package of public instruments can be assembled to address them.

Table 11 at the end of this chapter sets out in full the stakeholders, barriers and risk categories for utility-scale PV in Cambodia and suggests a comprehensive list of matching public instruments to address these barriers and risks[70]. *Table 7* below provides a summary of that table and highlights selected public derisking instruments which specifically address the risk categories identified in the financing cost waterfalls above (*Figure 8*).

Table 7: Selection of public instruments to achieve the investment targets for utility-scale PV

RISK CATEGORY	POLICY DERISKING INSTRUMENTS	FINANCIAL DERISKING INSTRUMENTS
Power Market Risk	• Establish long term on-grid PV targets • Strengthen capacities of independent market regulator • **Implement auction model** • **Develop standardized and well-designed PPA** document and process[71]	N/A
Permit Risk	• Streamline permitting/grid connection processes • Review and improve land administration	N/A
Social Acceptance Risk	N/A	N/A
Hardware Risk	• Streamlined, consistent and facilitated customs procedures; considered approach to customs tariffs • Develop certification and technology standards, and enforce standards	N/A
Digital Risk	N/A	N/A
Labor Risk	• Programs to develop a competitive, skilled labor market in solar PV (all roles)	N/A
Developer Risk	• Support to grow early-stage industry	N/A
Grid/Transmission Risk	• Develop a grid code for new renewable energy (RE) technologies/solar PV • **Develop and disseminate grid management study; technical support and software on grid management and planning** • Establish response timing targets for connection of new renewable/solar PV sources to the grid	• Include a "take-or-pay" clause in the standard PPA[72]
Off-taker Credit Risk	• Establish international best practice in off-taker's management and operations; implement sustainable cost recovery policies	• Government and/or development bank guarantees for PPA paymentsg
Financing Risk	• Reform domestic financial sector for green infrastructure investments • Expand options to meet collateral requirements for domestic lending to businesses • Strengthen domestic investors' familiarity with and capacity regarding solar PV	• Public loans to utility-scale solar developers[73]
Currency Risk	N/A[74]	N/A
Sovereign Risk	N/A	N/A

Source: modelling. See Table 11 for a full description of these instruments. "N/A" indicates "Not Applicable". Bold text represents high-priority instruments.

[70] This table was derived from the generic public instrument table for renewable energy in the DREI report (UNDP, 2013). Based on stakeholder consultation and investors' feedback, a number of changes have been made to the generic table to align with the Cambodian-specific context. The table was then used as the basis for the DREI analysis for utility-scale PV in Cambodia, including the interviews with investors.

[71] ADB is currently supporting RGC on a study to determine the ability of the grid to absorb solar energy (and the grid enhancement measures needed to ensure reliability and stability) as well as to establish a process for a competitive bidding process for utility-scale PV projects.

[72] A "take-or-pay" clause is a clause found in a Power Purchase Agreement (PPA) that essentially allocates risk between parties in the scenario where transmission line failures or curtailment (required by the grid operator) result in the IPP being unable to deliver the electricity generated by its renewable energy plant.

[73] The source of the public loan is likely to be an international multilateral or bilateral agency

[74] Not applicable because local currency is directly linked to USD.

For utility-scale PV (2030 target: 350 MW), the costs for policy derisking instruments until 2030 are estimated at USD 6.4 million and at USD 32.8[75] for financial derisking instrument.

Investors provided further qualitative feedback identifying the key priority derisking measure for utility-scale PV as the development and implementation of a transparent and competitive auction mechanism, with an accompanying standardized PPA. Furthermore, performing a grid stability study and transparently sharing findings has been highlighted as priority measure.

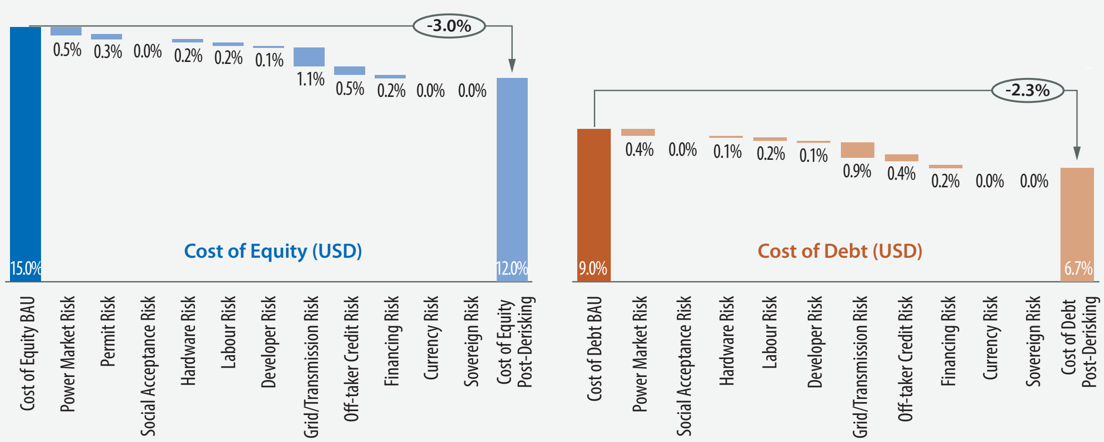
The full breakdown of each selected public instrument and its cost is provided in *Table 12*. Details of the assumptions and the methodology used to generate the cost estimates are available in Annex A.

Impact of public instruments on financing costs

The impact of the public instruments on reducing financing cost for utility-scale PV in Cambodia is illustrated in *Figure 9*. Based on the modelling analysis, the selected package of derisking instruments is anticipated to reduce the average cost of equity until 2030 by 3% down to 12%, and the cost of debt by 2.3% down to 6.7%.

A brief summary of the qualitative investor feedback on the public instruments discussed in the interviews and on their effectiveness in reducing financing cost in Cambodia is provided in *Table 8*.

Figure 9: Impact of public derisking instruments on reducing financing costs for utility-scale PV investments in Cambodia



Source: interviews with solar PV investors and developers; modelling; see Annex A for details of assumptions and methodology.
Note: the impacts shown are average impacts over the 2019-2030 modelling period, assuming linear timing effects.

[75] Different methodological approaches (e.g., face value, reserve, cost, no-cost) may be taken to costing financial derisking instruments. Here, a cost approach has been applied for the 'Take or pay clause in PPA' and a reserve approach was applied for credit lines and guarantees. Main cost for financial instruments in the utility-scale PV sector are opportunity costs in the form of a public guarantee for PPA payments, valuing USD 18.8 million until 2030.

Table 8: Investor feedback on the effectiveness of public instruments to address utility-scale PV risk category in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Power Market Risk	Investors would welcome a long-term strategy for renewables and stated that a clear short and medium-term outlook and a specific solar PV target, ideally broken down to different solar PV technologies, would be very effective. Investors also see the implementation of an transparent auction model for obtaining a generation concession, as well as a standardized, well-designed PPA process complying with international legal standards as highly effective.
Permits Risk	Investors rated the streamlining of permit processes and a recourse mechanism as effective. Any change in the process should reduce, and not increases bureaucracy. Investors highlighted the need for continuous efforts and monitoring of these instruments.
Social Acceptance Risk	Although rated as low risk, investors agreed that the promotion of the project and engagement with local communities to explain positive impacts can further increase social acceptance and community support.
Hardware Risk	Investors rated the effectiveness of streamlined, consistent and facilitated customs procedures and the considered approach to customs tariffs as high. The development and enforcement of certification and technology standards was mentioned as useful; however, investors expect hardware provider and EPC contractors to ensure that certified and proven technology is applied.
Labor Risk	Programs to develop a skilled labor market for solar farms covering different roles were rated as moderately effective. Investors pointed out that there are currently some solar PV labor training initiatives ongoing in Cambodia, but the results have not been yet seen. Training initiatives can help, but practical experience (i.e. amount of MW of solar PV installed) is considered most effective way to develop required skills and derisk labor risks.
Developer Risk	Investors would welcome early-stage industry support, which is rated it as moderately effective.
Grid/Transmission Risk	Investors rated the effectiveness of the proposed policy and financial derisking instruments as high. It has been pointed out, that it is crucial to clarify the grid absorption capacity as soon as possible since this is currently a very limiting factor in further electricity generation planning. Another point raised was that most development finance institutions can currently not lend to government entities directly and that this instrument better fits multilateral or bilateral entities without this limitation.
Off-taker Credit Risk	Strengthening capacities within the off-taker was rated moderately effective, whereas the provision of a guarantee to the IPP for PPA payments by either the government or an international financing institution was seen as a very powerful tool to overcome the off-taker credit risk.
Financing Risk	Investors rated both the policy and financial derisking instruments as highly effective. The value of improvements to the domestic financial sector to increase available local-currency capital has been highlighted, under recognition that it will take time. But investors also stated that international equity finance is readily available but that it lacks bankable projects in Cambodia due to non-compliance with international financial standards and investment procedures.
Currency Risk	Due to the generally low currency risk anticipation in Cambodia, the development of specific policy and financial derisking instruments was regarded of lower priority by interviewees. However, the proposed instruments have been scored as effective, especially the partial indexing of local currency tariffs in PPAs.
Sovereign Risk	Political risk insurances and guarantees offered by international organizations such as the World Bank and insurance companies were considered an effective financial derisking tool. But at the same time Investors were concerned about the lengthy process, bureaucracy and costs of such instruments.

Source: interviews with investors (equity investors/developers and debt investors).

5.3 Levelized Cost (Stage 3)

The levelized cost modelling compares today's financing costs with a post-derisking scenario with lower financing costs.

The modelling outputs in terms of LCOEs for utility-scale PV are illustrated in *Figure 10*.

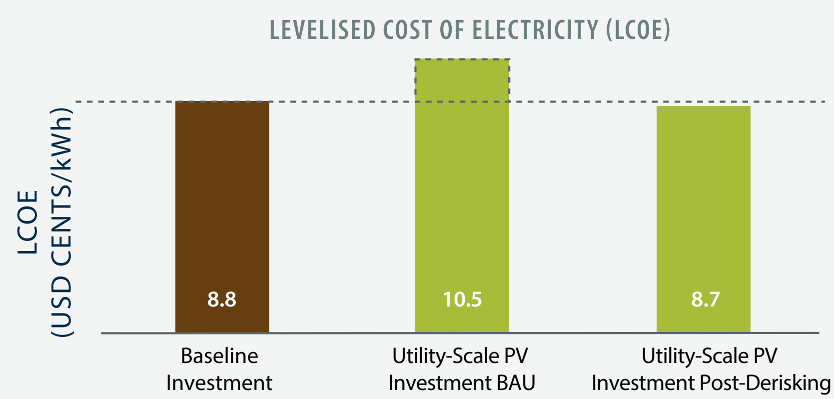
In the BAU scenario, utility-scale PV is more expensive than the baseline. The baseline technology mix assumes a marginal baseline approach of 50% coal (supercritical) and 50% large hydro[76,77]. This approach results in baseline LCOE of USD 8.8 cents per kWh[78], assuming unsubsidised fuel costs (see Annex A).

In comparison, utility-scale PV LCOE in the BAU scenario is estimated at USD 10.5 cents per kWh. This means that electricity from utility-scale PV requires a price premium of USD 1.7 cents per kWh over the baseline energy technology mix.

In the post-derisking scenario, the cost of utility-scale PV falls to USD 8.7 cents per kWh. As such, following government interventions to derisk the investment environment, and with resulting lower financing costs, utility-scale PV becomes cheaper and more affordable than the baseline electricity mix.

The utility-scale PV LCOE is sensitive to key assumptions such as investment costs and capacity factors, and LCOE results may vary based on the selected assumptions. See the following section on sensitivities for an analysis on how different assumptions impact the LCOE for utility-scale PV.

Figure 10: LCOEs for the baseline and utility-scale PV investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

[76] The marginal baseline approach entails the following: the model assumes that Cambodia in its business-as-usual scenario will continue to add super-critical coal and large hydro power plants as main means to increase its electricity generation capacity. This assumption is based on the publicly available generation expansion plan (MIME and IRENA, 2016).

[77] Although Cambodia is assumed to have considerable natural gas resources in the Gulf of Thailand, no concrete plans to introduce gas into the national electricity mix exist as of today, and therefore, gas has not been considered in the future baseline mix.

[78] The baseline reflects generation, and does neither include transmission and distribution costs, nor transmission losses. Furthermore, the baseline generation calculation is sensitive to technology choice assumptions, and does not reflect externalities including carbon pricing, water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health.

5.4 Evaluation (Stage 4)

Performance Metrics

The model's performance metrics, evaluating the impact of derisking on the envisioned 2030 targets for utility-scale PV investment in Cambodia, are illustrated in *Figure 11*.

Each of the four performance metrics takes a different perspective in assessing the performance of the derisking instrument package.

- The **investment leverage ratio** illustrates the efficiency of public instruments in attracting investment, comparing the total cost of public instruments with the resulting private-sector investment.

- The **savings ratio** takes a social perspective, comparing the cost of derisking instruments deployed versus the economic savings (from lower generation costs due to derisking) that accrue to society from deploying the instruments.

- The **affordability** metric takes an electricity consumer perspective, comparing the generation cost of utility-scale PV in the post-derisking scenario with the original BAU scenario.

- The **carbon abatement** metric takes a climate change mitigation perspective, considering the carbon abatement potential and comparing the carbon abatement costs (the cost per tonne of CO_2 abated). This can be a useful metric for comparing carbon prices.

Please see Annex A (Stage 4 – Evaluation) for detailed explanations of the function and rational of each metric.

Taken as a whole, the performance metrics demonstrate how the deployment of public derisking instruments can significantly increase the competitiveness and affordability utility-scale PV in Cambodia.

For instance, the leverage ratio illustrates that derisking is an efficient use of public funding.

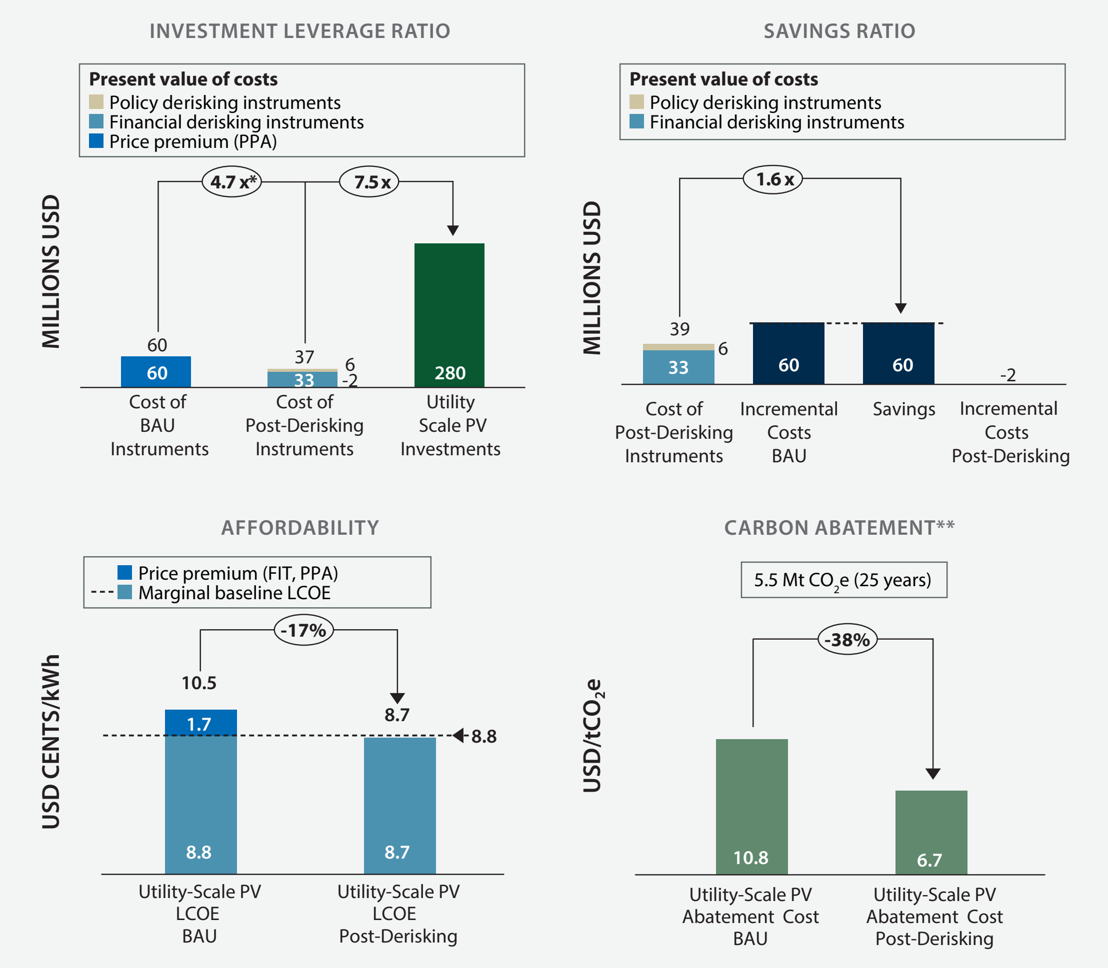
- For the leverage ratio, achieving the envisioned 2030 target of 350 MW in installed utility-scale PV capacity equates to a mobilization of USD 280 million in private sector investment. In the BAU scenario, the model estimates that achieving this target will require a price premium over 20 years of USD 60 million[79]. This results in a leverage ratio of 4.7x (i.e. the investments catalyzed are 4.7 times the amount spent on the price premium in a non-derisked environment). In the post-derisking scenario, the model estimates that this same investment target can be achieved with a package of derisking instruments valued at USD 37 million, including the cost of the reduced price premium and the costs of the derisking package. This raises the leverage ratio to 7.5x, indicating a significantly higher efficiency in terms of the use of public spending.

[79] 20 years corresponds to the assumed lifetime of the investment.

Also, the other performance metrics illustrated in *Figure 11* reveal the benefits of upfront derisking:

- for economic savings, the derisking leads to economic savings of USD 60 million, leveraging the costs of derisking by 1.6;
- electricity from utility-scale PV becomes 17% cheaper, from USD 10.5 cent to USD 8.7 cent;
- carbon abatement costs are reduced by 38%.

Figure 11: Performance metrics for the selected package of derisking instruments in promoting 350 MW of utility-scale PV investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

** The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 10.8 per tCO_2e is due to the price premium, in the post-derisking scenario, this breakdown for the total of USD 6.7 per tCO_2e is USD 1.2, USD 5.9 and USD -0.4, respectively.

Sensitivities

A set of sensitivity analysis has been performed for utility-scale PV. The objective of performing the sensitivity analysis is to gain a better understanding of the robustness of the outputs and to be able to test different scenarios.

Three types of sensitivity analysis have been performed.

1. Key input assumptions
2. Impact of carbon pricing on baseline scenario
3. Different solar import tax exemption scenarios

1. Sensitivity analysis on key input assumptions

Sensitivity analysis has been performed for the following input assumptions: (i) investment costs; (ii) capacity factor; and (iii) financing cost (CoE and CoD). In each case, all other assumptions have been kept constant[80]. In addition, a fourth analysis has been conducted, layering favorable and unfavorable input assumptions for utility-scale PV, creating an optimistic best-case, and a pessimistic worst-case scenario. The sensitivity analysis give an indication of the degree to which each input parameter affects the outputs. The results for this type of sensitivities are summarized in *Table 9*.

Highlights from the sensitivity analysis:

1. **Investment Costs.** Changes in solar investments costs have a significant impact on the LCOE of utility-scale PV. Lowering the investment costs by 20% in a derisked investment scenario leads to an LCOE of USD 7.4 cent per kWh. On the other hand, increasing the investment costs by 20% in a derisked investment scenario leads to an LCOE of USD 10.1 cent per kWh.

2. **Capacity Factor[81].** Changes in the capacity factor of solar PV have an even higher impact on the LCOE of utility-scale PV than changes in the investment costs. An assumed capacity factor increase of 20% leads to an LCOE as low as USD 7.3 cent per kWh in derisked investment scenario, while an assumed capacity factor decrease by 20% results in an LCOE of USD 11.0 cent per kWh.

3. **Layered Sensitivities** – *Best-case Scenario:* when layering favorable sensitivities, utility-scale PV reaches a LCOE as low as USD 5.9 cent/kWh, which is USD 2.9 cent lower than the baseline LCOE of USD 8.8 cent/kWh.

4. **Layered Sensitivities** – *Worst-case Scenario:* when layering unfavorable sensitivities, utility-scale PV reaches a LCOE as high as USD 13.3 cent/kWh, which is USD 4.5 cent higher than the baseline LCOE of USD 8.8 cent/kWh.

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[80] Note that keeping all other assumptions constant is a simplifying approach. For example, if higher capacity factors for solar PV are the result of improved solar modules (as opposed to improved solar PV sites), a different approach may be to also increase investment costs.

[81] The capacity factor is the ratio of the actual energy output compared to its potential output over a period of time. Limiting capacity factors for solar PV include times without sunshine (during nights or cloudy times) or downtime due to technical problems or maintenance.

Table 9: Utility-scale PV: summary of LCOE outputs for sensitivity analysis on key input assumptions

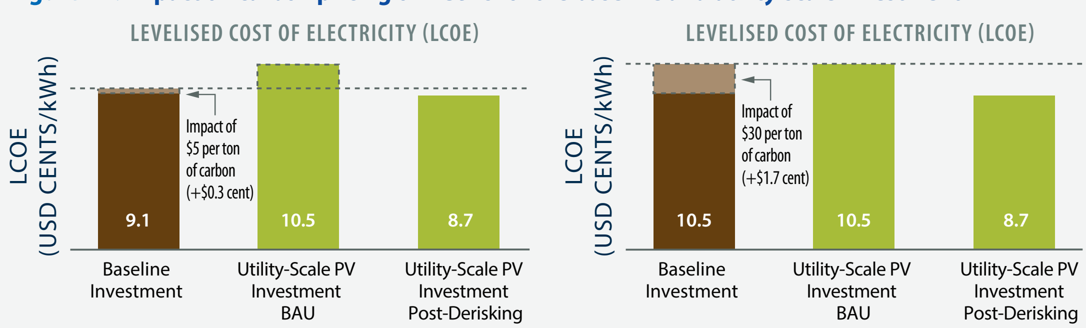
TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	BASELINE LCOE (USD/kWh)	BAU LCOE (USD/kWh)	POST-DERISKING LCOE (USD/kWh)
BASE CASE		0.088	0.105	0.087
INVESTMENT COSTS (Base Case: 0.8 per Wp)	Higher investment costs: +20% (0.96 per Wp)		0.122	0.101
	Lower investment costs: -20% (0.64 per Wp)		0.087	0.074
CAPACITY FACTOR (Base Case: 17.1%)	Higher capacity factor: +20% (20.5%)		0.087	0.073
	Lower capacity factor: -20% (13.7%)		0.131	0.110
FINANCING COSTS (Base Case: CoE: 15%, CoD: 9%)	Higher financing costs: 1% point (CoE: 16%, CoD:10%)		0.110	0.092
	Lower financing costs: 1% point (CoE: 14%, CoD:8%)		0.100	0.083
LAYERED SENSITIVITIES – Best-case Scenario	Lower investment costs: -20% (0.64 per Wp) Higher capacity factor: +20% (20.5%) Lower financing costs: 1% point (CoE: 14%, CoD: 8%)		0.069	0.059
LAYERED SENSITIVITIES – Worst-case Scenario	Higher investment costs: +20% (0.96 per Wp) Lower capacity factor: -20% (13.7%) Higher financing costs: 1% point (CoE:16, CoD: 10%)		0.160	0.133

2. Sensitivity analysis on the impact of carbon pricing

A sensitivity analysis on the impact of carbon price on the baseline LCOE has been performed to account for carbon emissions in the baseline energy mix. For this, two different carbon price scenarios with an assumed carbon price of USD 5 and USD 30 for each ton of carbon emitted have been modelled. *Figure 12* illustrates the impact of both carbon price scenarios on the baseline LCOE, in comparison with the pre- and post-derisking LCOE of utility-scale PV.

With an assumed price of USD 5 per ton of carbon, the baseline generation cost increases by USD 0.3 cent from USD 8.8 cent to USD 9.1 cent per kWh[82]. With a higher assumed price on carbon of USD 30 per ton, the baseline generation cost increases by USD 1.7 cent to USD 10.5 cent per kWh, increasing the price premium paid on electricity generated in the baseline energy mix.

Figure 12: Impact on carbon pricing on LCOEs for the baseline and utility-scale investment



Source: modelling; see Annex A for details of assumptions and methodology.

[82] Other externalities such as water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health have not been costed in the baseline energy mix LCOE.

3. Sensitivity analysis on solar import tax exemption scenarios

In addition to providing an analysis of the sensitivities of key input assumptions and carbon price, the report also provides a cost-benefit analysis[83] of a solar import tax exemption instrument. For this, the below three scenarios have been modelled.

1. Exemption of 10% import VAT on solar modules and inverters
2. Exemption of 35% import duties on inverters
3. Exemption of both 10% import VAT (solar modules and inverters) and 35% import duties (inverters)[84]

The results are summarized in *Table 10.*

In summary, all three solar import tax exemption scenarios lead to net benefits over the lifetime of utility-scale PV investments. The greatest benefit can be achieved by exempting both the VAT and import duties, estimated at net benefits of USD 5.4 million. Exempting the import VAT (on solar modules and inverters) result in net benefits of USD 4.3 million, while exempting solar duties alone (on inverters) leads to net benefits of USD 2.1 million.

Table 10: Utility-scale PV: summary of a cost-benefit analysis on solar import tax exemption scenarios

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	COST[85] (USD)	BENEFITS (USD)	NET BENEFITS (USD)	LCOE (USD/kWh)
BASE CASE	N/A	N/A	N/A	N/A	0.087
SOLAR IMPORT TAX EXEMPTION	Exemption of 10% import VAT (on solar modules and inverters)	10.6m	14.9m	4.3m	0.083
	Exemption of 35% import duties on solar PV equipment (only inverters and batteries)	5.0m	7.1m	2.1m	0.085
	Exemption of BOTH 10% import VAT and 35% import duties	13.4m	18.8m	5.4m	0.082

[83] Costs and benefits are calculated over the investment lifetime of utility-scale PV of 25 years. Costs represent foregone revenue for the government for not-collected import taxes on solar equipment; benefits represent the reduction of generation costs (i.e. through reduced investment costs) due to the tax exemption. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that the reduction in electricity generation costs is higher than the potential income from import taxes, making import tax exemption on solar PV equipment an economically viable instrument.

[84] It is the author's understanding that an import VAT of 10% applies to all imported solar PV equipment, while specific import duties of 35% apply only for inverters and batteries (not for solar modules).

The combined modelling applied a multiplicative approach, i.e. the exemption of 35% on inverters and batteries was applied on the already reduced LCOE after reduction of 10% import VAT on solar modules, inverters and batteries.

[85] Results refer to the post-derisking scenario, i.e. it is assumed that the solar import tax exemption takes effect in a derisked investment environment as modelled in this study.

Public Instrument Table for Utility-Scale PV

Table 11: The modelling exercise's public instrument table for utility-scale PV (Part I)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
1. Power Market Risk	Risk arising from limitations and uncertainties in the energy market, and/or sub-optimal regulations to address these limitations and support energy markets	*Market outlook:* lack of or uncertainties regarding governmental renewable energy strategy and targets
		Market access and prices: limitations related to energy market liberalization; uncertainties related to access, the competitive landscape and price outlook for renewable energy; limitations in design of standard PPAs and/or PPA tendering procedures, limitations and/or uncertainty in tax treatment of renewable energy
		Market distortions: lack of level playing field due to favorable treatment (fuel subsidies; tax, duty, VAT treatment, government guarantees) for fossil fuels and large scale hydropower
2. Permits Risk	Risk arising from the public sector's inability to efficiently and transparently administer renewable energy- related licensing and permits, including land acquisition	*Bureaucracy:* Labour-intensive, complex processes and long time-frames for obtaining licences and permits (generation, EIAs, land title) for renewable energy projects
		Transparency: Perceived corruption. No clear recourse mechanisms
		Land: Limitations in administrative aspects of land acquistion for utility-scale renewable energy.
3. Social Acceptance Risk	Risks arising from lack of awareness and resistance to renewable energy from end-users, special interest groups	*Awareness:* Lack of awareness of renewable energy amongst key stakeholders including: end-users, local residents and special interest groups (e.g. unions)
		Resistence: Social and political resistance related to NIMBY concerns, special interest groups

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Establish transparent, long-term national renewable energy strategy and targets	Regular updates of national energy planning, including national-level resource inventory/ mapping, technology options, and renewable energy target formulation		
Establish a harmonized, well-regulated energy market, with cornerstone instruments to address price and market-access risk for renewable energy projects	(i) Ongoing legislative reform to implement well-designed and harmonized policies; (ii) establish an independent energy market regulator; (iii) implement FiT and PPA tendering*, including well-designed standard PPA, (iv) clear and long term tax treatment for renewable energy		
Balanced treatment across sectors and reform of fossil fuel subsidies	Harmonized application of favored treatment across sectors; asssessment of existing direct/ indirect subsidies, studies to assess the impact of phase-out/down of such subsidies, design and promotion of replacement legislation		
Streamline processes for permits	Establish an on-line one-stop-shop for renewable energy permits; reduction of process steps; clear timelines for processing; harmonisation of requirements		
Contract enforcement and recourse mechanisms	Enforce transparent practices and fraud avoidance mechanisms; establish effective recourse mechanisms, with clear timelines for resolution		
Reform of land administration	Well administered system for land management, including registry, transfer of title, and balanced tax approach		
Awareness-raising campaigns	Implement active publicity, media and awareness campaign targeting key stakeholder groups		
Support community based projects	Establish favourable local (e.g. municipal) policies and pilot community owned renewable energy projects); assist in establishing appropriate legal vehicles for community models	Financial products by development banks expressly targeting community projects and legal vehicles	Depends on specific circumstances, can include, as necessary: public loans; public guarantees for commercial loans; public equity; currency and concessionality of products may vary

* Note: This instrument can be/have elements of a direct financial incentive.

Table 11: The modelling exercise's public instrument table for utility-scale PV (Part II)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
4. Hardware Risk	Risk arising from limitations in the quality and availability of utility-scale hardware; issues arising from inefficiencies in the customs process	*Quality, suitability and availability of hardware:* Lack of access to information on quality, reliability (performance) and cost of hardware; insuitabilty of hardware to local conditions; limitations in infrastructure (e.g. roads) impacting transport
		If applicable, local content requirements and manufacture of hardware: challenging local content requirments; lack of local industrial presence and experience with manufacturing hardware
		Customs: Cumbersome customs/clearing process for importing hardware, leading to delays in delivery; where applicable, punitive customs tariffs for utility-scale renewable energy
5. Labour Risk	Risks arising from the lack of skilled and qualified potential employees	Lack of a competitive labour market of educated, skilled and qualified potential employees, leading to higher costs, hiring non-local staff and suboptimal performance
6. Developer Risk	Risks arising from limitations in the IPP's management capability and ability to execute on financing and business plan	Lack of C-suite talent and experience to ensure effective execution (business planning, securing financing, resource assessment, plant design, operations and maintenance) and to manage challenges (limited information, unforeseen events)
7. Grid/ Transmission Risk	Risks arising from limitations in grid management and transmission infrastructure	*Grid code, management and connection:* Lack of standards for the integration of intermittent, renewable energy sources into the grid; limited experience or suboptimal track-record in grid management and stability; lack of responsiveness and delays in connection of new renewable energy sources to the transmission network
		Transmission infrastructure: inadequate or antiquated grid infrastructure, including high transmission losses, and lack of lines from the renewable energy source to load centres; uncertainties for construction of new transmission infrastructure
8. Off-Taker Credit Risk	Risks arising from the off-taker's poor credit quality and an IPP's reliance on payments	Limitations in the off-taker's (electricity purchaser's) credit quality, corporate governance, management and operational track-record or outlook; unfavourable policies regarding off-taker's cost-recovery arrangements

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Technology standards; research and development	Test centre for research and development into product adaptation, such as wind turbine adaptation to local conditions; government efforts to facilitate transport (e.g., flexible application of road transport rules)		
Harmonized approach to local content and industrial policy	Balanced and phased local content requirments; industrial policy for domestic manufacturing	Financial products by development banks to assist domestic manufacturers in gaining access to capital	Depends on specific circumstances, can include, as necessary: public loans; public guarantees for commercial loans; public equity; currency and concessionality of products may vary
Streamlined, consistent and facilitated customs procedures; considered approach to customs tariffs	Reduction of customs administrative steps, including possible online functionality; public response timelines; effective and expedited recourse mechanisms. Full cost-benefit economic assessment and benchmarking of tariffs; phase-out/down of punitive tariffs; introduction of import tariff holidays and VAT exemptions*		
Programmes to develop competitive, skilled labour market in utility-scale renewable energy (all roles)	Apprenticeships, certificates and education programmes to build skills in utility-scale renewable energy (engineering, installation, marketing, business management)		
Government support to grow early-stage industry	Government support for establishing industry association; government support for initial industry conferences; dissemination of top-level, national resource assessment findings; government sponsored academic studies		
Strengthen transmission operator's operational performance, grid management and formulation of grid code	(i) Develop a grid code for new renewable energy technologies; (ii) sharing of international best practice in grid management; (iii) establish timing targets for connection of new renewable sources to the grid	Include a "take-or-pay" clause in the standard PPA	"Take-or-pay" clause in PPA whereby IPP is reimbursed for grid failure (black-out, brown-out) and/or curtailment (due to mismatches in grid management of supply/demand)
Policy support for national grid infrastructure planning and development	Develop and regularly update a long-term national transmission/grid plan to include intermittent renewable energy	Financial products by development banks to transmission companies in gaining access to capital	Depends on specific circumstances, can include, as necessary: public loans; public guarantees for commercial loans; public equity; currency and concessionality of products may vary
Strengthen off-taker's performance	Establish international best practice in off-taker's management, operations and corporate governance; implement sustainable cost recovery policies	Government and/or development bank guarantees for PPA payments	Government (e.g., Ministry of Finance) letter of support for PPA payments to IPPs; development bank partial risk guarantee for PPA payments; development bank public loans to IPPs

* Note: This instrument can be/have elements of a direct financial incentive.

Table 11: The modelling exercise's public instrument table for utility-scale PV (Part III)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
9. Financing Risk	Risks arising from general scarcity of investor capital (debt and equity) in the particular country, and investors' lack of information and track record in utilty-scale renewable energy	*Capital scarcity - under-developed domestic financial sector:* Low number of financial actors (debt, equity, insurance, pensions)
		Capital scarcity - liquidity constraints in domestic banking: Limited availability of long term domestic loans due to high banking reserve requirements
		Capital scarcity - competing incentives/mandates: domestic financial sector (banks, pension funds) mandated to invest in alternative, competing sectors
		Limited experience with utility-scale renewable energy: Lack of information, assessment skills and track-record for renewable energy projects amongst investor community; lack of network effects (investors, investment opportunities) found in established markets; lack of familiarity and skills with project finance structures
10. Currency Risk*	Risks arising from currency mismatch between hard currency debt/equity and domestic currency revenues	Uncertainty due to volatile local currency; unfavourable FX rate movements; inability to economically hedge FX exposure due to illiquid FX derivative markets.
11. Sovereign Risk	Risk arising from a mix of cross-cutting political, economic, institutional and social characteristics in the particular country which are not specific to utility-scale renewable energy	Limitations and uncertainty related to conflict, political instability, economic performance, weather events/natural disaster, legal governance, ease of doing business, crime and law enforcement, and infrastructure in the particular country

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

* Note this risk category only applies if financing is in hard currency.

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Liberalise domestic financial sector	Liberalisation and introduction of competition into domestic financial sector	Financial products by development banks to assist IPPs to gain access to capital/funding	Depends on specific circumstances, typically public loans; currency and concessionality of products may vary
Reform reserve requirements for domestic lending to businesses	Balanced approach to liquidity requirements, assessing trade-offs between financial stability and renewable energy/electrification objectives		
Reform financial sector incentives for investing in specific sectors	Balanced approach to incentives across all sectors; introduce incentives, targets and mandatory lending requirements for renewable energy/SHS/electrification		
Strengthen domestic investors' (debt, equity, institutions, intermediaries) familiarity with and capacity regarding on-grid rooftop PV and aggregative financing models	Dialogues, events and conferences for utility-scale renewable energy; sharing of successful project finance structures; workshops/training for investors on utilty-scale renewable energy assessment		
Government support for long term development of liquid domestic FX derivative markets	Regulatory reforms enabling derivative trading for local securities exchanges; steering of large government FX hedging contracts to domestic FX markets.	Risk sharing mechanisms to address currency risk	Partial indexing of local currency tariffs in PPAs, so that IPPs are reimbursed for local currency depreciation of tariff
		Risk sharing products by development banks to address political risk	Provision of political risk insurance to equity holders covering (i) expropriation, (ii) political violence, (iii) currency restrictions and (iv) breach of contract

Summary Data Table

Table 12: Summary modelling assumptions for utility-scale PV in Cambodia

ROOFTOP PV TARGET AND RESOURCES	
2030 Target (in MW)	350
Capacity Factor (%)	17.1%
Total Annual Energy Production for Target (in MWh)	525,000
BASELINE ENERGY MIX	
Coal	50%
Hydro	50%
Grid Emission Factor (tCO_2e/MWh)	0.458
GENERAL COUNTRY INPUTS	
Effective Corporate Tax Rate (%)	20%
Public Cost of Capital (%)	8%

	BUSINESS-AS-USUAL SCENARIO	POST DERISKING SCENARIO
FINANCING COSTS		
Capital Structure		
Debt/Equity Split	50%/50%	62.5%/37.5%
Cost of Debt		
Concessional public loan	N/A	6.0%
Commercial loans with public guarantees	N/A	N/A
Commercial loans without public guarantees	9.0%	6.7%
Loan Tenor		
Concessional public loan	N/A	10 years
Commercial loans with public guarantees	N/A	N/A
Commercial loans without public guarantees	10 years	10 years
Cost of Equity	15.0%	12.0%
Weighted Average Cost of Capital (WACC) (After-tax)	11.1%	7.8%
INVESTMENT		
Total Investment (USD million)	$280.0	$280.0
Debt (USD million)		
Concessional public loan	$0.0	$43.8
Commercial loans with public guarantees	$0.0	$0.0
Commercial loans without public guarantees	$140.0	$131.3
Equity (USD million)	$140.0	$105.0
Private Sector Equity	N/A	N/A
Public Sector Equity	N/A	N/A
COST OF PUBLIC INSTRUMENTS		
Policy Derisking Instruments (USD million, present value)		
Power Market Risk Instruments	N/A	$1.4
Permits Risk Instruments	N/A	$1.5
Social Acceptance Risk Activities	N/A	N/A
Hardware Risk Activities	N/A	$0.8
Labour Risk Activities	N/A	$0.6
Developer Risk Activities	N/A	$0.2
Grid/Transmission Risk Instruments	N/A	$0.9
Off-taker Credit Risk Instruments	N/A	$0.2
Financing Risk Activities	N/A	$0.8
Total	**N/A**	**$6.4**
Financial Derisking Instruments (USD million, present value)		
Grid/Transmission Risk Instruments	N/A	$3.1
Off-taker Credit Risk Instruments	N/A	$18.8
Financing Risk Instruments	N/A	N/A
Public Loans	N/A	$10.9
Public Guarantees for Commercial Loans	N/A	N/A
Currency Risk Instruments	N/A	N/A
Sovereign Risk Instruments	N/A	N/A
Total	**N/A**	**$32.8**
Direct Financial Incentives (USD million)		
Present Value of 20 year PPA Premium	**$59.6**	**($2.1)**

Chapter 6

On-Grid – Rooftop PV Results

On-Grid – Rooftop PV Results

6

This chapter sets out the modelling results for rooftop PV in Cambodia. The results present a set of cost-effective public derisking measures that allow meeting the study's investment targets for rooftop PV (C&I) of 175 MW[86] by 2030. The results are organized in terms of the DREI methodology's four stages, as introduced in Chapter 2 of this report.

6.1 Risk Environment (Stage 1)

Interviews

Data on the risk environment were obtained from 22 structured interviews held with domestic and international investors and project developers who are considering or are actively involved in on- and off-grid solar PV opportunities in Cambodia and the Southeast Asian region. These investors reflect a variety of interests, both strategic and financial.

Financing Cost Waterfalls

The analysis of the contribution of investment risks to higher financing costs for rooftop PV in Cambodia is illustrated in the financing cost waterfall in *Figure 13*.

Based on data from interviews focusing on the risk environment of rooftop PV, it is estimated in this report that financing costs today for rooftop PV are 17% for the CoE, and 10% for the CoD[87]. These are substantially higher than in the best-in-class country estimates[88], which are at 9% CoE and 5% CoD. As for utility-scale PV, investors in rooftop PV are also experiencing unfavorable equity and debt capital structures, and overall, higher financing costs are contributing to rooftop PV to be less competitive to the dominating coal- and hydro-based power generation.

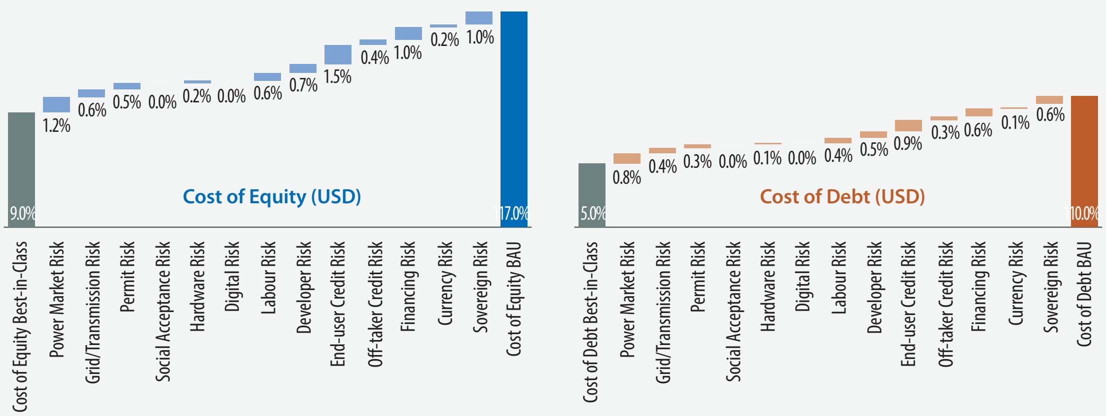
A range of investment risks currently contribute to these higher financing costs for rooftop PV in Cambodia. The risk categories with the largest impact on elevated financing costs are (i) *power market risk*, related to uncertainty in the outlook for rooftop PV, the absence of schemes such as a net-metering or FiT scheme, and the uncertainty on grid integration of C&I rooftop PV, especially regarding the current capacity – and energy charge tariff and permitting system; (ii) *end-user credit risk,* concerning the credit-worthiness of commercial and industrial electricity end-users; and (iii) *financing risk,* relating to the scarcity of capital from international and domestic markets.

[86] The overall investment target for rooftop PV of 350 MW has been divided equally into 175 MW in the commercial and industrial (C&I) sector and 175 MW in the residential sector. Except for the total capital investment costs, the report's modelling is solely performed on rooftop PV for the C&I sector and does not further refer to the residential sector.

[87] USD-denominated cost of equity and debt

[88] For rooftop PV the authors have applied a 'synthetic' best-in-class approach, where a synthetic best-in-class country was created.

Figure 13: Impact of risk categories on financing costs for rooftop PV (C&I) investments in Cambodia, business-as-usual scenario (BAU)



Source: interviews with rooftop PV investors and developers; modelling: the authors have applied a 'synthetic' best-in-class approach, where a synthetic (or imaginary) best-in-class country was created with data based on interviews and the authors' knowledge and expertise; see Annex A for details of assumptions and methodology.

During the interviews, investors and project developers further provided qualitative feedback on the risk environment for rooftop PV in Cambodia. A summary is provided in *Table 13* (parts I and II).

Table 13: Qualitative investor feedback on risk categories for rooftop PV investment in Cambodia Part (I)

RISK CATEGORY	INVESTOR FEEDBACK
Power Market Risk	This risk category has a high impact on financing costs. Most investors were concerned about the absence of legal clarity for rooftop PV installations and the uncertainty in the strategy, the absence of schemes such as a net-metering or FiT scheme and targets in this sector. EAC's recent regulation on the integration of solar PV into the grid (issued January 2018) has been perceived positively and as a step in the right direction. However, due the capacity charge introduced in this regulation, it makes it difficult for smaller rooftop PV project to be financially viable. It is also feared that a rising rooftop PV market and the consequently reduced electricity demand from the grid can have impact on EDC's business plan. Similar to feedback on the utility-scale PV sector, investors believe that EDC's main concerns include uncertainty regarding the management of intermittent rooftop PV and its effect on the grid, as well as the overall supply and demand planning (including existing contracts).
Grid/Transmission Risk	This risk category has a high impact on financing costs. Investors identified the lack of an interconnection grid code/standard as the primary factor elevating grid transmission risk. Furthermore, there is concern in regard to the potential absorption rate of solar power into the grid, which increases the investment uncertainty for investors.
Permit Risk	This risk category has a medium impact on financing costs. Interviewees pointed out that EAC's recent regulation is still not fully understood in regard to the current capacity and energy charge tariff, and the overall permit procedure which causes investment uncertainty.
Social Acceptance Risk	This risk category has a low impact on financing costs. Investors and project developers agreed that rooftop PV is generally regarded positively within Cambodian civil society, and that no social resistance is expected.
Hardware Risk	This risk category has a low impact on financing costs. Most investors assessed the risk of underperforming as low due to the performance guarantee commonly provided by the hardware supplier or EPC contractor. However, problems that arise during custom clearing were mentioned to be quite frequent.

Table 13: Qualitative investor feedback on risk categories for rooftop PV investment in Cambodia Part (II)

RISK CATEGORY	INVESTOR FEEDBACK
Digital Risk	This risk category has a low impact on financing costs. Investors perceived this risk and its potential impact to the commercial and industrial sector as low.
Labor Risk	This risk category has a medium impact on financing costs. Investors shared their experience that finding qualified personnel is a real challenge as the rooftop PV market is still small and no organized labor market for it exists yet.
Developer Risk	This risk category has a high impact on financing costs. Interviewees shared the view that, similar to the labor risk, no rooftop PV market exists yet so high-quality developers with experience and proven track records in Cambodia are scarce. Major risk concerns are seen in lack of experience (MW installed), overall project management and logistic capabilities.
End-user Credit Risk	This risk category has a high impact on financing costs. Investors are concerned about the lack of a consumer credit data industry, and its high risk for rooftop PV investments in C&I.
Off-taker Credit Risk	This risk category has a medium impact on financing costs. Most interviewees agreed that EDC is generally a reliable off-taker.
Financing Risk	This risk category has a medium impact on financing costs. Investors pointed out that no domestic debt finance is available at the moment. Some interviewees believe that if other risks are tackled, domestic finance will develop automatically.
Currency Risk	This risk category has a low impact on financing costs. All investors agreed that the currency risk is not very high due the fact that the Cambodian Riel is pegged to the USD, and that most loans and payments are conducted in USD.
Sovereign Risk	This risk category has a medium impact on financing costs. All interviewees agreed that Cambodia has a promising economic and social development prospects. Investors agreed that it is difficult for foreign investors to judge this risk reliably and that they are therefore often rather concerned about it. Domestic investors, on the hand, are usually better informed and are, to some extent, even involved in governmental high-level discussions and feel more comfortable to predict sovereign-related risks.

6.2 Public instruments (Stage 2)

Selection and costing of public instruments

Having identified the key investment risks for rooftop PV, a package of public instruments can then be assembled to address them.

Table 18 at the end of this chapter sets out in full the stakeholders, barriers and risk categories for rooftop PV in Cambodia and suggests a comprehensive list of matching public instruments to address these barriers and risks[89]. *Table 14* on next page provides a summary of that table and highlights selected public derisking instruments which specifically address the risk categories identified in the financing cost waterfalls above (*Figure 13*).

[89] This table was derived from the generic public instrument table for renewable energy in the DREI report (UNDP, 2013). Based on stakeholder consultation and investors' feedback, a number of changes have been made to the generic table to align with the Cambodian-specific context. The table was then used as the basis for the DREI analysis for rooftop PV in Cambodia, including the interviews with investors.

Table 14: Selection of public instruments to achieve the investment targets for rooftop PV

RISK CATEGORY	POLICY DERISKING INSTRUMENTS	FINANCIAL DERISKING INSTRUMENTS
Power Market Risk	• Establish long term rooftop PV targets • Strengthen capacities of independent market regulator • **Implement supporting scheme, e.g. FiT and/or Net-Metering** • **Expansion of regulations to low-voltage customers[90], including balanced solar capacity charges**	N/A
Permit Risk	• Streamlined process for permits, one-stop-shop and recourse mechanisms • Clear zoning approach	N/A
Social Acceptance Risk	N/A	N/A
Hardware Risk	• Streamlined, consistent and facilitated customs procedures • Develop certification and technology standards, and enforce standards	N/A
Digital Risk	N/A	N/A
Labor Risk	• Programs to develop a competitive, skilled labor market in rooftop PV (all roles)	N/A
Developer Risk	Government support to grow early-stage industry	N/A
Grid/Transmission Risk	• Develop a grid code for solar PV • Policy support for national grid infrastructure planning/development	• Include a "take-or-pay" clause in the standard PPA[90]
Off-taker Credit Risk	Establish international best practice in off-taker's management, operations; improve sustainable cost recovery policies	• Government and/or development bank guarantees for PPA paymentsg
End-user Credit Risk	• Facilitate growth of end-user credit data industry	Credit lines and loan guarantees to commercial banks' lending to rooftop PV developers
Financing Risk	• Reform domestic financial sector to green infrastructure investment • Expand options for meeting collateral requirements for domestic lending to businesses • Strengthen domestic investors' familiarity/capacity regarding rooftop PV • Regulations and clarity on tax for asset backed securities	
Currency Risk	N/A[91]	N/A
Sovereign Risk	N/A	N/A

Source: modelling. See *Table 18* for a full description of these instruments. "N/A" indicates "Not Applicable". Bold text represents high-priority instruments.

[90] 3i is currently supporting RGC on a study on low-voltage connections of rooftop PV systems.
[91] Not applicable because local currency is directly linked to USD.

For rooftop PV (2030 target for C&I: 175 MW), the costs for policy derisking instruments until 2030 are estimated at USD 7.2 million and at USD 8.6 million[92] for financial derisking instruments.

Based on investors qualitative feedback, the EAC regulation on general conditions for installing and operating solar PV systems in Cambodia is considered an important step to attract private investment in rooftop PV, particular for medium- and high-voltage systems. An additional opportunity exists to expand on this by making low-voltage customers eligible to grid synchronization while introducing a supportive scheme, such as a net-metering or FiT scheme. Furthermore, the government can consider revising the recently introduced solar capacity and energy charge in order to create a balanced level-playing field with other technologies.

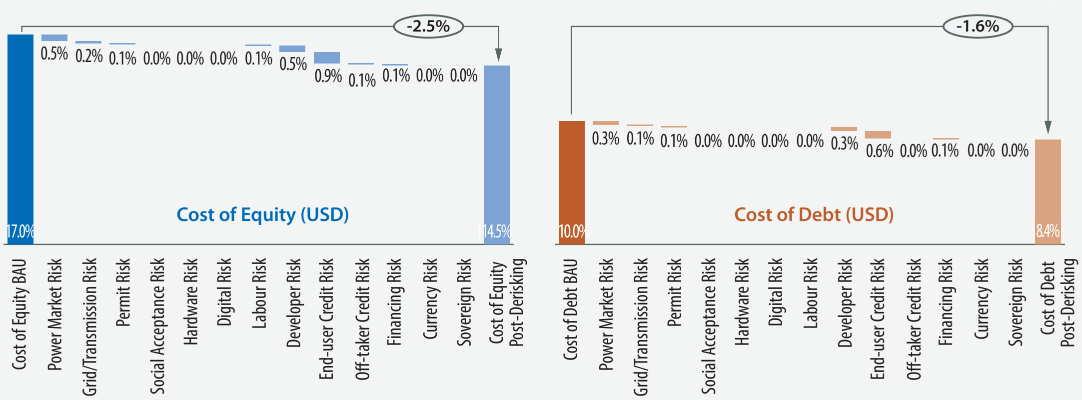
The full breakdown of each selected public instrument and its cost is provided in *Table 19*. Details of the assumptions and the methodology used to generate the cost estimates are available in Annex A.

Impact of public instruments on financing costs

The impact of the public instruments on reducing financing cost for rooftop PV in Cambodia is illustrated in *Figure 14*. Based on the modelling analysis, the selected package of derisking instruments is anticipated to reduce the average cost of equity until 2030 by 2.5% down to 14.5%, and the cost of debt by 1.6% down to 8.4%.

A summary of the qualitative investor feedback on the public instruments discussed in the interviews and on their effectiveness in reducing financing cost in Cambodia is provided in *Table 15*.

Figure 14: Impact of public derisking instruments on reducing financing costs for rooftop PV (C&I) investments in Cambodia



Source: interviews with solar PV investors and developers; modelling; see Annex A for details of assumptions and methodology.
Note: the impacts shown are average impacts over the 2019-2030 modelling period, assuming linear timing effects.

[92] Different methodological approaches (e.g., face value, reserve, cost, no-cost) may be taken to costing financial derisking instruments. Here, a reserve approach was applied for credit lines and loan guarantees.

Table 15: Investor feedback on the effectiveness of public instruments to address rooftop PV (C&I) risk category in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Power Market Risk	Interviewees rated the proposed policy derisking instruments as highly effective, with the establishment of a well-designed regulatory regime for distributed on-grid rooftop PV named as key measure. Within this regulatory regime, it was recommended to include a supportive scheme, such as a net-metering system for larger rooftop projects (little additional costs for the government while potentially receiving a limited amount of electricity for free, without endangering the stability of the grid). In addition, a low FiT scheme for smaller projects (i.e. low voltage projects as defined in EAC's latest solar PV regulation draft) was suggested. It was argued that this would show that rooftop PV can already compete with coal and offer cheap electricity to EDC, while providing investors with a small and important way to generate some extra cash flow and diversify risk.
Grid/Transmission Risk	Most interviewees scored the proposed derisking instruments as quite effective. Similar to the utility-scale solar PV sector, clarifying the absorption capacity of the grid was mentioned as a very important next step. Furthermore, developing a grid code for new rooftop solar PV in order to ensure grid stability was rated a high priority measure.
Permit Risk	Streamlining permit and grid connections processes for rooftop PV was rated as a highly effective policy measure.
Social Acceptance Risk	Proposed derisking instruments for the social acceptance risk were rated as moderately effective. But it was pointed out that due to the very low anticipated problems in this risk category no derisking measures are needed.
Hardware Risk	Interviewees agreed that clear, transparent and aligned custom processes for solar PV hardware would be an effective measure to reduce the risk of a potential project delay due to unforeseen custom problems. A VAT exemption and import tariff holiday for solar PV hardware was also seen as an effective tool to motivate the application of higher quality solar equipment. Interviewees were sceptical about the effect of a working capital fund as means to reduce hardware risk.
Digital Risk	Interviewees did not see the need for deploying derisking instruments at the moment.
Labor Risk	As for the utility-scale PV sector, programs to develop a skilled labor market for rooftop PV were considered moderately effective. Results from currently ongoing solar PV technician training initiatives remain to be seen but training inefficiencies were already identified by the private sector. The most effective way to build the required skills and experiences is encouraging the development of more rooftop PV projects by reducing investment risks in the other risk categories.
Developer Risk	Interviewees rated the suggested derisking instruments as moderately effective. Instruments to increase awareness and include solar PV in high-level discussions are regarded as very important to get the rooftop PV market started as soon as possible so progresscan be made towards developing a mature market. One suggested approach includes public support to the Solar Energy Association of Cambodia (SEAC) so it can engage in discussions on solar PV targets, regulations, permits, custom procedures and other concerns of project developers and investors.
End-user Credit Risk	Interviewees rated the effectiveness of the proposed derisking instruments moderately to high. The development of a credit data registry is seen as very important. However, it was pointed out that such a system requires several years of data history to be maximally effective.
Off-taker Credit Risk	Strengthening capacities and applying international best practice in off-taker's management was rated moderately effective.
Financing Risk	Investors and project developers agreed that strengthening domestic bank's familiarity and capacity regarding rooftop PV and aggregating financing vehicles would be a very effective way to develop the local financing market. Other derisking instruments were met with moderate expectations in terms of their effectiveness. Some investors suggested putting in place a public support program that would include concessional loans to domestic banks that then on-lend to the private sector for more favorable financing terms.
Currency Risk	Due to the generally low currency risk anticipation in Cambodia, the development of specific policy and financial derisking instruments has been regarded as low priority by interviewees.
Sovereign Risk	Interviewees expresses doubts on the effectiveness of political risk insurance (PRI) and do not think that risk sharing products by development banks are an effective option for the rooftop PV sector as they are more applicable for utility-scale solar farms or very large project portfolios.

Source: interviews with investors (equity investors/developers and debt investors).

6.3. Levelized Cost (Stage 3)

The levelized cost modelling compares today's financing costs with a post-derisking scenario with lower financing costs.

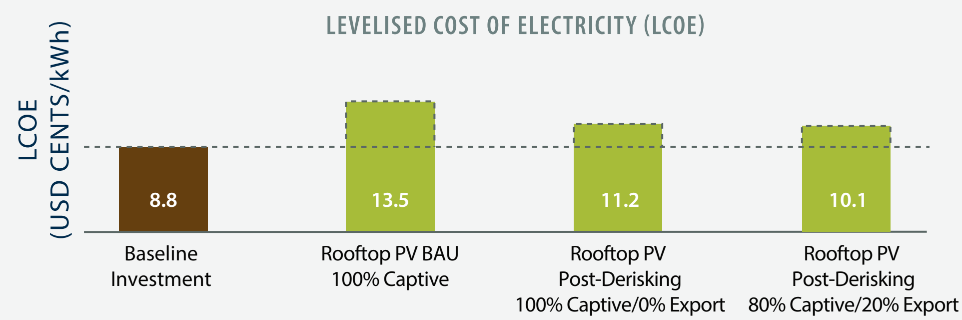
The results of the generation cost comparison, expressed through the LCOE, are illustrated in *Figure 15* below.

In the BAU scenario, rooftop PV is more expensive than the baseline. The baseline technology mix is the same as for utility-scale PV and assumes a marginal baseline approach of 50% coal (supercritical) and 50% large hydro[93, 94]. This approach results in baseline generation costs of USD 8.8 cents per kWh[95]. In comparison, rooftop PV energy costs in the BAU scenario is estimated at USD 13.5 cents per kWh[96]. This means that electricity from rooftop PV requires a price premium of USD 4.7 cents per kWh over the baseline energy technology mix.

For the post-derisking scenario, two investment cases have been modelled. The first case assumes a 100% captive use of generated electricity (i.e. no export to the grid), while the second assumes that 80% of the rooftop generated electricity is used captively with 20% exported to the grid at the national consumer grid tariff for C&I at USD 16 cent per kWh[97]. In the 100% captive use case, the cost of rooftop PV falls to USD 11.2 cents per kWh, while the 20% export option reduces the cost further to USD 10.1 cents per kWh. Hence following government interventions to derisk the investment environment and with resulting lower financing costs, the price premium for rooftop PV is reduced by roughly 50% in case one, and 70% in case two.

The rooftop PV LCOE is sensitive to key assumptions such as investment costs and capacity factors, and LCOE results may vary based on the selected assumptions. See the following section on sensitivities for an analysis on how different assumptions impact the LCOE for rooftop PV.

Figure 15: LCOEs for the baseline and rooftop PV investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

[93] In doing so, the model assumes that Cambodia in its business-as-usual scenario will continue to add super-critical coal and large hydro power plants as main means to increase its electricity generation capacity. This assumption is based on the publicly available generation expansion plan (MME and IRENA, 2016).

[94] Although Cambodia is assumed to have considerable natural gas resources in the Gulf of Thailand, no concrete plans to introduce gas into the national electricity mix exist, and therefore gas has not been considered in the future baseline mix.

[95] The baseline reflects generation, and does not include transmission and distribution costs, nor transmission losses. Further the baseline generation calculation is sensitive to technology choice assumptions, and does not reflect externalities including carbon pricing, water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health.

[96] Potential impacts of the recently issued rooftop PV regulation are not included in the modelling.

[97] The national consumer grid tariff ranges from USD 9.5 – 18.25 cents per kWh based on type of consumer (C&I, residential) and voltage (low, medium, high). For details about electricity tariffs, see Annex B.

6.4 Evaluation (Stage 4)

Performance Metrics

The model's performance metrics, evaluating the impact of derisking on the envisioned 2030 targets for rooftop PV (C&I) investment in Cambodia, are illustrated in *Figure 16*.

Each of the four performance metrics takes a different perspective in assessing the performance of the derisking instrument package.

- The **investment leverage ratio** illustrates the efficiency of public instruments in attracting investment, comparing the total cost of public instruments with the resulting private-sector investment.
- The **savings ratio** takes a social perspective, comparing the cost of derisking instruments deployed versus the economic savings that accrue to society from deploying the instruments.
- The **affordability** metric takes an electricity consumer perspective, comparing the generation cost of rooftop PV (C&I) in the post-derisking scenario with the original BAU scenario.
- The **carbon abatement** metric takes a climate change mitigation perspective, considering the carbon abatement potential and comparing the carbon abatement costs (the cost per tonne of CO_2 abated). This can be a useful metric for comparing carbon prices.

Please see Annex A (Stage 4 – Evaluation) for detailed explanations of the function and rational of each metric.

Taken as a whole, the performance metrics demonstrate how the deployment of public derisking instruments can significantly increase the competitiveness and affordability rooftop PV in Cambodia.

For instance, the leverage ratio illustrates that derisking is an efficient use of public funding.

- For the investment leverage ratio, achieving the envisioned 2030 target of 175 MW in installed rooftop PV (C&I) capacity[98] equates to USD 152 million in private sector investment. In the BAU scenario, the model estimates that achieving this target will require a price premium over 25 years of USD 83 million[99]. This results in a leverage ratio of 1.8x (i.e. the investments catalyzed are 1.8 times the amount spent on the price premium in a non-derisked environment). In the post-derisking scenario, the model estimates that this same investment target can be achieved with a package of derisking instruments valued at USD 38 million[100], including the cost of the reduced price premium and the costs of the derisking package. This raises the leverage ratio to 4.0x, indicating a higher efficiency in terms of the use of public spending.

Also, the other performance metrics illustrated in *Figure 16* reveal the benefits of upfront derisking:

- for economic savings, the derisking leads to economic savings of USD 61 million, leveraging the costs of derisking by 3.9;

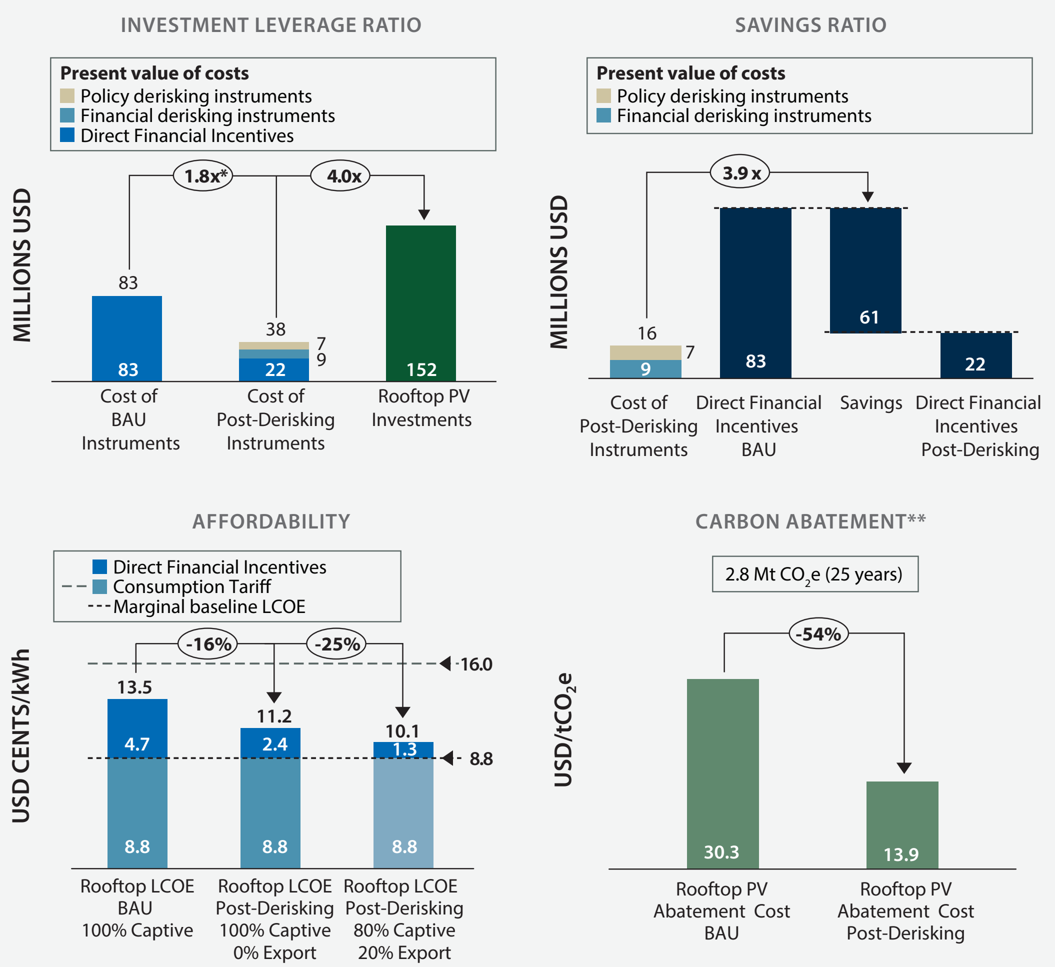
[98] The overall investment target for rooftop PV is 350 MW and has been divided into 175 MW in the commercial and industrial (C&I) sector, and 175 MW in the residential sector. In the DREI exercise, modelling is solely performed on rooftop PV for the C&I sector. Modelling on the residential sector has not been performed.

[99] 20 years corresponds to the assumed lifetime of the investment.

[100] Assumes the rooftop PV business case in which 20% of electricity is exported to the grid at the national consumer grid tariff for C&I.

- electricity from rooftop PV becomes 25% cheaper – from USD 13.5 cent to USD 10.1 cent (with the assumption that 80% of the rooftop generated electricity is used captively and 20% exported to the grid at the national consumer grid tariff for C&I at USD 16 cent per kWh);
- carbon abatement costs are reduced by 54%.

Figure 16: Performance metrics for the selected package of derisking instruments in promoting 175 MW of rooftop PV (C&I) investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2030 investment target may not be met.

** The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments and the price premium. While in the BAU scenario, the total of USD 30.3 per tCO_2e is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD 13.9 per tCO_2e is USD 2.6, USD 3.1 and USD 8.2, respectively.

Sensitivities

A set of sensitivity analysis has been performed for rooftop PV. The objective of performing the sensitivity analysis is to gain a better understanding of the robustness of the outputs and to be able to test different scenarios.

Three types of sensitivity analysis have been performed:

1. Key input assumptions
2. mpact of carbon pricing on baseline scenario
3. Different solar import tax exemption scenarios

1. Sensitivity analysis on key input assumptions

These have been performed for the following input assumptions: (i) investment costs; (ii) capacity factor; (iii) financing cost (CoE and CoD). In each case, all other assumptions have been kept constant. In addition, a fourth analysis has been conducted, layering favorable and unfavorable input assumptions for rooftop PV, creating an optimistic best-case and a pessimistic worst-case scenario. The sensitivity analysis provides an indication of the degree to which each input parameter affects the outputs. The results for this type of sensitivity are summarized in *Table 16*.

Highlights from the sensitivity analysis:

1. **Investment Costs.** Changes in investments costs have a significant impact on the LCOE of rooftop PV. Lowering the investment costs by 20% in a derisked investment scenario leads to an LCOE of USD 7.3 cent per kWh. Increasing investment costs by 20% leads to an LCOE of USD 12.8 cent per kWh.

2. **Capacity Factors.** Changes in the capacity factor of solar PV have an almost equally strong impact on the LCOE of rooftop PV as changes in investment costs. An assumed capacity factor increases by 20% leads to an LCOE as low as USD 7.7 cent per kWh in derisked investment scenario, while an assumed capacity decreases of 20% results in an LCOE of USD 13.6 cent per kWh.

3. **Layered Sensitivities** – *Best-case Scenario:* When layering favorable sensitivities, rooftop PV reaches a LCOE as low as USD 5.0 cent/kWh, which is USD 3.8 cent lower than the baseline LCOE of USD 8.8 cent/kWh.

4. **Layered Sensitivities** – *Worst-case Scenario:* When layering unfavorable sensitivities, rooftop PV reaches a LCOE as high as USD 17.9 cent/kWh, which is USD 9.1 cent higher than the baseline LCOE of USD 8.8 cent/kWh.

Table 16: Rooftop PV (C&I): summary of LCOE outputs for sensitivity analysis on key input assumptions

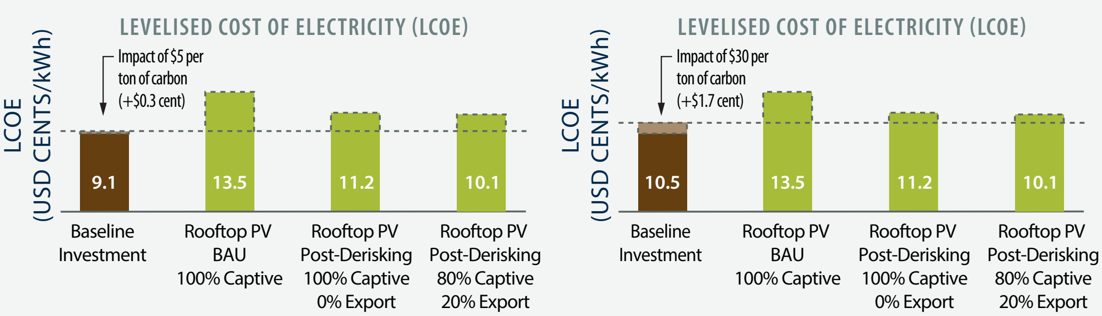
TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	BASELINE LCOE (USD/kWh)	BAU LCOE (USD/kWh)	POST-DERISKING LCOE (USD/kWh)
BASE CASE		0.088	0.135	0.101
INVESTMENT COSTS (Base Case: 0.87 per Wp – C&I)	Higher investment costs: +20% (1.04 per Wp)		0.161	0.128
	Lower investment costs: -20% (0.70 per Wp)		0.108	0.073
CAPACITY FACTOR (Base Case: 17.1%)	Higher capacity factor: +20% (20.5%)		0.112	0.077
	Lower capacity factor: -20% (13.7%)		0.168	0.136
FINANCING COSTS (Base Case: CoE: 17%, CoD:10%)	Higher financing costs: 1% point (CoE: 18%, CoD:11%)		0.141	0.106
	Lower financing costs: 1% point (CoE: 16%, CoD:9%)		0.129	0.095
LAYERED SENSITIVITIES – Best-case Scenario	Lower investment costs: -20% (0.70 per Wp) Higher capacity factor: +20% (20.5%) Lower financing costs: 1% point (CoE: 16%, CoD: 9%)		0.086	0.050
LAYERED SENSITIVITIES – Worst-case Scenario	Higher investment costs: +20% (1.04 per Wp) Lower capacity factor: -20% (13.7%) Higher financing costs: 1% point (CoE:18, CoD: 11%)		0.211	0.179

2. Sensitivity analysis on the impact of carbon pricing

As for utility-scale PV, a sensitivity analysis on the impact of a carbon price on the baseline LCOE has been performed to account for the emittance of carbon emissions in the baseline energy mix. The same two carbon price scenarios with an assumed carbon price of USD 5 and USDS 30 for each ton of carbon emitted have been modelled. *Figure 17* illustrates the impact of both carbon price scenarios on the baseline LCOE, in comparison with the pre- and post-derisking LCOE of rooftop PV.

With an assumed price of USD 5 per ton of carbon, the baseline generation cost increases by USD 0.3 cent from USD 8.8 cent to USD 9.1 cent per kWh[101]. With a higher assumed price on carbon of USD 30 per ton, the baseline generation cost increases by USD 1.7 cent to USD 10.5 cent per kWh, making rooftop PV in a derisked investment environment, with 20% grid-export option, a more affordable source of electricity. This analysis illustrates that the baseline mix LCOE demonstrates a high sensitivity to carbon pricing.

Figure 17: Impact of carbon pricing on LCOEs for the baseline and rooftop PV investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

[101] Other externalities such as water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health have not been costed in the baseline energy mix LCOE.

3. Sensitivity analysis on solar import tax exemption scenarios

The report also conducted a cost-benefit-analysis[102] of a solar import tax exemption instrument, modelling the below three scenarios.

1. Exemption of 10% import VAT on solar modules and inverters
2. Exemption of 35% import duties on inverters
3. Exemption of both 10% import VAT (solar modules and inverters) and 35% import duties (inverters)[103]

The results are summarized in *Table 17*.

In summary, all three solar import tax exemption scenarios lead to net benefits over the lifetime of rooftop PV investments. The greatest benefit can be achieved by exempting both the VAT and import duties, estimated at net benefits of USD 15.6 million. Exempting the import VAT (on solar modules and inverters) result in net benefits of USD 11.5 million, while exempting solar duties alone (on inverters for rooftop PV) leads to net benefits of USD 4.5 million.

Table 17: Rooftop PV (C&I): summary of a cost-benefit analysis on solar import tax exemption scenarios

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	COST[104] (USD)	BENEFITS (USD)	NET BENEFITS (USD)	LCOE (USD/kWh)
BASE CASE	N/A	N/A	N/A	N/A	0.101
SOLAR IMPORT TAX EXEMPTION	Exemption of 10% import VAT (on solar modules and inverters)	7.0m	18.5m	11.5m	0.090
	Exemption of 35% import duties on solar PV equipment (only inverters and batteries)	2.7m	7.2m	4.5m	0.097
	Exemption of BOTH 10% import VAT and 35% import duties	9.5m	25.1m	15.6m	0.087

102 Costs and benefits are calculated over the investment lifetime of rooftop PV of 25 years. Costs represent foregone revenue for the government for not-collected import taxes on solar equipment; benefits represent the reduction of generation costs (i.e. through reduced investment costs) due to the tax exemption. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that the reduction in electricity generation costs is higher than the potential income from import taxes, making import tax exemption on solar PV equipment an economically viable instrument.

103 It is the author's understanding that an import VAT of 10% applies to all imported solar PV equipment, while specific import duties of 35% apply only for inverters and batteries (not for solar modules).

The combined modelling applied a multiplicative approach, i.e. the exemption of 35% on inverters and batteries was applied on the already reduced LCOE after reduction of 10% import VAT on solar modules, inverters and batteries.

104 Results refer to the post-derisking scenario, i.e.it is assumed that the solar import tax exemption takes effect in a derisked investment environment as modelled in this study.

Public Instrument Table for Rooftop PV

Table 18: The modelling exercise's public instrument table Rooftop PV (Part I)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
1. Power Market Risk	Risk arising from limitations and uncertainty in the power market regarding market outlook, access, price and competition for on-grid, rooftop PV	*Market outlook:* Lack of or uncertainty regarding on-grid, rooftop PV strategy and targets
		Market access and prices: Limitations related to: where applicable, unliberalized market struture; lack of or limitations in feed-in tariff or net metering policies, including pricing; punitive fixed fees; uncertainty regarding competitive landscape; in sophisticated markets
		Market distortions: lack of level playing field due to favorable treatment (fuel subsidies, tax, VAT, duties, guarantees) for utility-scale generation and, where applicable, diesel (gensets for unreliable grids)
2. Grid/ Transmission Risk	Risks arising from limitations in grid management, performance and infrastructure	*Grid code and management:* Lack of standards for the integration of on-grid, rooftop PV into the grid; limited experience or suboptimal track-record of grid operator with intermittent sources (e.g., grid management and stability)
		Grid performance and infrastructure: challenges from grid brownouts disrupting rooftop PV performance (e.g. inverters); inadequate or antiquated grid infrastructure; transformer over-voltages (low to high voltage) at distribution sub-stations due to reverse power flow from on-grid rooftop PV
3. Permits Risk	Risk arising from the public sector's administration and enforcement of on-grid rooftop PV and building permits and zoning	*Bureaucracy: Labour-intensive, complex processes and long time-frames for obtaining permits (building, fire permits) for on-grid rooftop PV*
		Transparency: Perceived corruption. No clear recourse mechanisms
		Zoning: uncertainty regarding possible future obstruction of rooftop PV from competing buildings/objects
4. Social Acceptance Risk	Risks arising from lack of awareness and resistance to on-grid rooftop PV products and services in communities	Resistance by general public and local communities due to unfamiliarity, mis-information/perceptions, and poor historic hardware quality of on-grid rooftop PV; resistance from incumbent businesses (e.g., utilities, diesel based generation) disrupted by on-grid rooftop PV
		Split incentive barriers between landlord and tenants, and in multi-family buildings, limit demand for on-grid rooftop PV

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Establish transparent, long term targets for on-grid rooftop PV	Regular updates of national power market planning, including resource mapping, technology options, and integrated domestic power system modeling across technologies (short, medium and long-term)		
Establish well-designed regulatory regime for distributed on-grid rooftop PV	(i) Liberalization of power market, including an independent power market regulator; (ii) implement well-designed feed-in tariff* or net-metering policies, including any fixed fees, which balance financial viability with incentives on end-user system sizing and sectoral targets		
Balanced treatment across sectors and reform of fossil fuel subsidies	'Harmonized application of favored treatment across sectors; assessment of existing subsidies; phase-out/down of subsidies*; awareness campaigns accompanying reform; design of transfer programs to vulnerable social groups		
Formulation of grid code and strengthen transmission operator's operational performance, grid management	(i) Develop a grid code for on-grid rooftop PV; (ii) sharing of international best practice in grid management		
Policy support for national grid infrastructure planning and development	Develop and regularly update an integrated national grid plan (transmission and distribution), to include on-grid rooftop PV		
Streamline processes for permits	One-stop-shop for rooftop PV permits; balanced permitting requirements and zoning for rooftop-PV; clear timelines for processing;		
Contract enforcement and recourse mechanisms	Enforce transparent practices and fraud avoidance mechanisms; establish effective recourse mechanisms, with clear timelines for resolution		
Clear approach to zoning	Development of transparent zoning regulations on building heights/massing; strong enforcement of zoning regulations		
Develop and coordinate ongoing public awareness campaigns	Public awareness campaigns, stakeholder dialogues and workshops between policy makers, NGOs, communities, community leaders and end users		Clearly defined building zonging
Develop community-based recruitment strategies and policies	Establish policies incentivizing community-based solar, and/or enhanced/virtual net metering in multi-family buildings		

* Note: This instrument can be/have elements of a direct financial incentive.

Table 18: The modelling exercise's public instrument table Rooftop PV (Part II)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
5. Hardware Risk	Risk arising from limitations in the quality and availability of on-grid rooftop PV hardware; lack of standards in credit terms, leading to working capital challenges; issues arising from inefficiencies in the customs process	*Quality of hardware:* Lack of information or uncertainty on quality, reliability (performance) and cost of hardware, lack of clarity or uncertainty regarding government technical standards to ensure safety of on-grid rooftop PV hardware *Availability of hardware:* Where applicable, lack of an open market for buying hardware, including the availabilty from international suppliers *Credit terms:* Lack of uniform/conducive/standardised credit terms on purchase of on-grid rooftop PV hardware, leading to working capital shortages *Customs:* Cumbersome customs/clearing process for importing rooftop PV hardware, leading to delays in delivery; lack of consistent enforcement of tariffs; where applicable, punitive customs tariffs
6. Digital Risk	Risks arising from use of cellular networks, quality of software, cyber security, and abuse of consumer data	*Cellular networks:*over-dependence on a single operator for reliable cell service limits ability for effective monitoring *Software:* poor software performance for smart meters and remote monitoring *Cyber security:* vulnerabilities of developers and individual rooftop PV systems to cyber attack *Abuse of consumer data:* possible abuse of consumer data privacy on ongrid rooftop PV usage; lack of understanding/clarity on uses of consumer information
7. Labour Risk	Risks arising from the lack of skilled and qualified potential employees	Lack of a competitive labour market of educated, skilled and qualified potential employees, leading to higher costs, hiring non-local staff and suboptimal performance

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Develop certification and standards for hardware; adopt internationally recognized standards and share best practices, where applicable	Establish minimum certification standards and required warranties; transparently develop, update (as necessary), disseminate, and enforce standards for technical performance and safety		
Ensure an open, competitive marketplace for buying hardware	Balance industrial policy objectives, where applicable, for domestic manufacturers, with open markets for international manufacturers		Depends on specific circumstances, can include, as necessary: public loans; public guarantees for commercial loans; public equity; currency and concessionality of products may vary
		Provision of working capital funds for early-stage on-grid rooftop PV companie	
Streamlined and consistent customs procedures; considered approach to customs tariffs	Reduction of customs administrative steps; public response timelines; effective and expedited recourse mechanisms; consistent enforcement. Full cost-benefit economic assessment and benchmarking of tariffs; phase-out/down of punitive tariffs; introduction of import tariff holidays and VAT exemptions*		
Well-designed telecom regulations enabling competitive coverage	Regulation on coverage areas and a competitive market for cellular services		
Government support for industry associations	Software/technology working groups in industry asociations to advocate for developer's software needs		
Government cyber security initiatives	Government initiatives including establishing a cyber security entity, provding guidance and investigating incidents; promotion of cyber security insurance.		
Institute balanced consumer data protection regulations	Facilitate the development of clear and transparent guidelines on data use by companies in the on-grid rooftop PV company ecosystem; raise awareness among consumers; government enforcement of data privacy laws		
Programmes to develop competitive, skilled labour market in on-grid rooftop PV (all roles)	Apprenticeships, certificates and education programmes to build skills in on-grid rooftop PV (engineering, installation, marketing, business management)		

* Note: This instrument can be/have elements of a direct financial incentive.

Table 18: The modelling exercise's public instrument table Rooftop PV (Part III)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
8. Developer Risk	Risks arising from limitations in on-grid roopftop PV's management capability, transparency in data and contractual terms, and its creditworthiness and cash flow.	*Management capability:* lack of C-suite talent and experience to ensure effective execution (business planning, service offering, securing financing, customer acquisition, distribution and installation, operations and maintenance), and to manage challenges (limited information, unforeseen events*)*
		Data transparency and contractual standardization: inability of on-grid, rooftop PV company to provide sufficient transparency on key performance indicators, and to generate a large enought volume of standardized assets to access aggregative, low-cost financing
		On-grid rooftop PV company creditworthiness and cash flow strength: inability of on-grid rooftop PV company to secure low-cost financing due to (i) lack of credit worthiness or (ii) insufficient cash flow and/or pipeline of quality receivables
9. End-User Credit Risk	Risk arising from end-users' willingness and ability to pay for electricity	*Information on end-user credit worthiness:* Lack of end-user (residential, C&I) credit data with which to assess the financial status of end-users
		Poor credit worthiness and non-payment: Risk of delayed, reduced or non-payment by end-users
10. Off-Taker Credit Risk	Risks arising from the off-taker's non-payment for electricity sold to the grid	Limitations in the off-taker's (electricity purchaser's) credit quality, corporate governance, management and operational track-record or outlook; unfavourable policies regarding off-taker's cost-recovery arrangements

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Government support to grow early-stage industry	Government support for establishing industry association; government support for initial industry conferences; dissemination of top-level, national resource assessment findings; government sponsored academic studies (for example, on-demand evolution)		
Government support to support innovative aggregative finance	Government support, via industry associations, to coordinate stakeholders (e.g., on-grid rooftop PV companies, financial intermediaries, investors) on industry-wide recommendations for best practice standardized data sets (KPIs) and contractual terms		
		Public loans, guarantees and/or equity to on-grid rooftop PV companies, and/or aggregative financing vehicles	Public loans to on-grid rooftop PV companies; public guarantees to commercial banks lending to on-grid rooftop PV companies, and to investors in aggregative SPVs; public equity investments; currency and concessionality of products may vary
Facilitate growth of consumer credit data industry	Promotion of balanced privacy and financial regulations allowing for collection of credit data on end-users (both residential and C&I) by the private sector; piloting of fintech solutions/platforms for credit data analysis		
Where applicable, public schemes targeting low creditworthy residential end-users	Cross subsidization* of low-credit worthy groups via preferential tariffs and/or capital subsidies. Non-targeted groups absorb less attractive tariff structures	Public loans, guarantees and/or equity to on-grid rooftop PV companies, and/or aggregative financing vehicles	Public loans to on-grid rooftop PV companies; public guarantees to commercial banks lending to on-grid rooftop PV companies, and to investors in aggregative SPVs; public equity investments; currency and concessionality of products may vary
Strengthen off-taker's performance	Establish international best practice in off-taker's management, operations and corporate governance; implement sustainable cost recovery policies		

* Note: This instrument can be/have elements of a direct financial incentive.

Table 18: The modelling exercise's public instrument table Rooftop PV (Part IV)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
11. Financing Risk	Risks arising from scarcity of domestic investor capital (debt and equity) for on-grid rooftop PV companies, and domestic investors' lack of familiarity with on-grid rooftop PV and appropriate financing structures	*Capital scarcity - under-developed domestic financial sector:* Low number of financial actors (debt, equity, insurance, pensions)
		Capital scarcity - liquidity constraints in domestic banking: Limited availability of long term domestic loans due to high banking reserve requirements
		Capital scarcity - competing incentives/mandates: domestic financial sector (banks, pension funds) mandated to invest in alternative, competing sectors
		Capital scarcity - aggregative financing models: lack of regulatory and tax clarity on aggregative models, such as asset backed securities;
		Limited domestic investor experience with on-grid rooftop PV, including aggregative financing models: Lack of information, assessment skills and track-record for on-grid rooftop PV companies amongst domestic investor community; limited/lack of financial intermediaries and advisors; lack of network effects (investors, investment opportunities) found in established markets; lack of famliarity with SPV, warehouse vehicle legal structures; lack of awareness on pricing for aggregative financing models
12. Currency Risk*	Risks arising from currency mismatch between hard currency debt/equity and domestic currency revenues	*Uncertainty due to volatile local currency; unfavourable FX rate movements; inability to economically hedge FX exposure due to illiquid FX derivative markets.*
13. Sovereign Risk	Risk arising from a mix of cross-cutting political, economic, institutional and social characteristics in the particular country which are not specific to on-grid rooftop PV	Limitations and uncertainty related to conflict, political instability, economic performance, weather events/natural disaster, legal governance, ease of doing business, crime and law enforcement, and infrastructure in the particular country

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

* Note this risk category only applies if financing is in hard currency.

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Liberalise domestic financial sector	Liberalisation and introduction of competition into domestic financial sector	Public loans, guarantees and/or equity to on-grid rooftop PV companies and/or aggregative financing	Public loans to on-grid rooftop PV companies; public guarantees to commercial banks lending to on-grid rooftop PV companies, and to investors in aggregative SPVs; public equity investments; currency and concessionality of products may vary
Reform reserve requirements for domestic lending to businesses	Balanced approach to liquidity requirements, assessing trade-offs between financial stability and renewable energy/electrification objectives		
Reform financial sector incentives for investing in specific sectors	Balanced approach to incentives across all sectors; introduce incentives, targets and mandatory lending requirements for on-grid rooftop PV		
Regulatory and tax framework for aggregative financing models	Regulatory and tax reforms for asset backed securities for on-grid rooftop PV		
Strengthen domestic investors' (debt, equity, institutions, intermediaries) familiarity with and capacity regarding on-grid rooftop PV and aggregative financing models	Dialogues, events and conferences for on-grid rooftop PV; sharing of successful deal structures, including aggregative models; transparent data on pricing of financial products, including aggregative models; workshops/training for investors on on-grid rooftop PV assessment and innovative financial structuring		
Government support for long term development of liquid domestic FX derivative markets	Regulatory reforms enabling derivative trading for local securities exchanges; steering of large government FX hedging contracts to domestic FX markets.	Financial products to transfer currency risk to public sector	Government subsidised or facilitated F/X hedging programmes for on-grid rooftop PV companies

Summary Data Table

Table 19: Summary modelling assumptions for rooftop PV (C&I) in Cambodia

ROOFTOP PV TARGET AND RESOURCES	
2030 Target (in MW)	175
Capacity Factor (%)	17.1%
Total Annual Energy Production for Target (in MWh)	262,500
BASELINE ENERGY MIX	
Coal	50%
Hydro	50%
Grid Emission Factor (tCO_2e/MWh)	0.458
GENERAL COUNTRY INPUTS	
Effective Corporate Tax Rate (%)	20%
Public Cost of Capital (%)	8%

	BUSINESS-AS-USUAL SCENARIO	POST DERISKING SCENARIO
FINANCING COSTS		
Capital Structure		
Debt/Equity Split	25%/75%	75%/25%
Cost of Debt		
Concessional public loan	N/A	8.0%
Commercial loans with public guarantees	N/A	8.4%
Commercial loans without public guarantees	10.0%	8.4%
Loan Tenor		
Concessional public loan	N/A	10 years
Commercial loans with public guarantees	N/A	10 years
Commercial loans without public guarantees	10 years	10 years
Cost of Equity	17.0%	14.5%
Weighted Average Cost of Capital (WACC) (After-tax)	14.8%	10.6%
INVESTMENT		
Total Investment (USD million)	$152.3	$152.3
Debt (USD million)		
Concessional public loan	$0.0	$19.0
Commercial loans with public guarantees	$0.0	$19.0
Commercial loans without public guarantees	$38.1	$38.1
Equity (USD million)	$114.2	$76.1
Private Sector Equity	N/A	N/A
Public Sector Equity	N/A	N/A
COST OF PUBLIC INSTRUMENTS		
Policy Derisking Instruments (USD million, present value)		
Power Market Risk Instruments	N/A	$1.7
Grid/Transmission Risk Instruments	N/A	$0.4
Permits Risk Instruments	N/A	$1.2
Social Acceptance Risk Activities	N/A	N/A
Hardware Risk Activities	N/A	$0.8
Digital Risk Instruments	N/A	N/A
Labour Risk Activities	N/A	$0.6
Developer Risk Activities	N/A	$0.2
End-User Credit Risk Instruments	N/A	$0.7
Off-taker Credit Risk Instruments	N/A	$0.2
Financing Risk Activities	N/A	$1.4
Currency Risk Instruments	N/A	N/A
Total	**N/A**	**$7.2**
Financial Derisking Instruments (USD million, present value)		
Currency Risk Instruments	N/A	N/A
End-User Credit Risk Instruments		
Public Loans	N/A	$4.8
Public Guarantees for Commercial Loans	N/A	$3.8
Total	**N/A**	**$8.6**
Direct Financial Incentives (USD million)		
Present Value of Price Premium over Bestline	**$83.5**	**$22.5**

Chapter 7

Off-Grid – Solar-Battery Mini-Grid Results

Off-Grid – Solar-Battery Mini-Grid Results

7

This chapter sets out the modelling results for solar-battery MGs in Cambodia. The results present a set of cost-effective public derisking measures that allow meeting the study's illustrative solar-battery MG building block[105] of 10 MW by 2025. The results are organized in terms of the DREI methodology's four stages, as introduced in Chapter 2 of this report.

7.1 Risk Environment (Stage 1)

Interviews

Data on the risk environment were obtained from 22 structured interviews held with domestic and international investors and project developers who are considering or are actively involved in on- and off-grid solar PV opportunities in Cambodia and the Southeast Asian region. These investors reflect a variety of interests, both strategic and financial.

Financing Cost Waterfalls

The analysis of the contribution of investment risks to higher financing costs for solar-battery MG in Cambodia is illustrated in the financing cost waterfall in *Figure 18*.

Based on data from interviews focusing on the risk environment of solar-battery MG, it is estimated in this report that financing costs today for solar-battery MGs are 19% for the CoE and 11% for the CoD[106, 107]. These are substantially higher than in the best-in-class country estimates[108], which are at 11% CoE and 5% CoD. Financing costs are also significantly higher than for on-grid solar PV in Cambodia, reflecting significant higher risk expectation for investments in solar-battery MG.

Figure 18 illustrates how a range of investment risks currently contribute to higher financing costs for solar-battery MG[109]. The risk categories with a significant impact on elevated financing costs are (i) *energy market risk*, related to uncertainty regarding market outlook and price, and particular the lack of designated national off-grid electricity service areas for MGs and information on geographical national grid extension plans, (ii) *developer risk*, related to the lack of high quality off-grid project developers with proven track record, and the absence of a centralised information platform on solar-battery MG developers, (iii) *Labor Risk*, due to a lack of skilled personnel for off-grid system installation and maintenance, (iv) *financing risk*, relating to the scarcity of capital from international and domestic markets, and (v) *end-user credit risk*, arising from the end-users ability and willingness to pay for electricity services.

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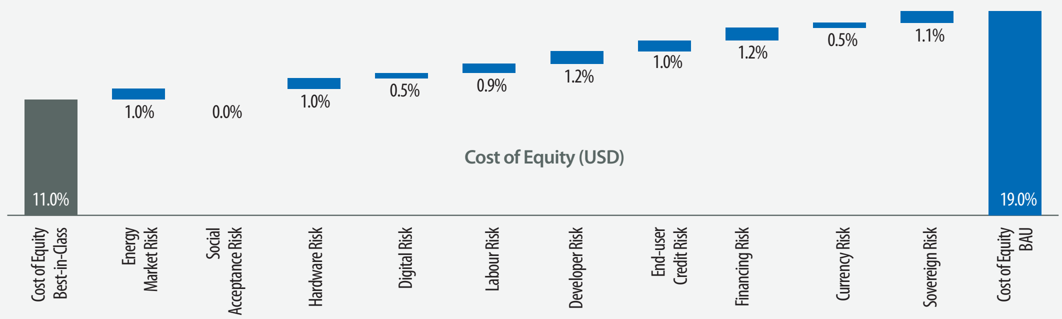
105 10 MW building blocks targets can be multiplied. A number of 10 MW units will be needed to achieve full and improved electrification.
106 USD-denominated cost of equity and debt.
107 The author assumed the same risk environment for both off-grid solar PV technologies.
108 For solar-battery MGs the author has applied a 'synthetic' best-in-class approach, where a synthetic best-in-class country.
109 Only the impact on equity financing is shown for solar-battery MG as there is no debt financing anticipated in the business-as-usual scenario.

Figure 18: Impact of risk categories on financing costs for solar-battery MG investments in Cambodia, business-as-usual (BAU) scenario



Source: interviews with rural electricity enterprises (REEs) and potential solar-battery MG investors and developers; modelling: the author has applied a 'synthetic' best-in-class approach, where a synthetic (or imaginary) best-in-class country was created with data based on interviews and the authors' knowledge and expertise; see Annex A for details of assumptions and methodology.

During the interviews, investors and project developers further provided qualitative feedback on the risk environment for solar-batter MG in Cambodia. A summary is provided in *Table 20*.

Table 20: Qualitative investor feedback on risk categories for solar-battery MG investment in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Energy Market Risk	This risk category has a high impact on financing costs. Several concerns were raised on the current regime, i.e. in which REEs and EDC, are the only parties which can hold generation and distribution concessions for potential MGs. Similar to SHS, interviewees were most concerned about project uncertainty due to the lack of designated national off-grid electricity service areas, as well as information on the specific, geographical national grid extension plans. If the grid arrives when the MG is already in place, the project owner has to apply national grid tariffs, regardless whether or not the system is actually connected to the grid.
Social Acceptance Risk	This risk category has a low impact on financing costs. Interviewees shared the view that people in remote areas see solar PV as an opportunity to access more and stable electricity, and that social resistance is very unlikely.
Hardware Risk	This risk category has a high impact on financing costs. Investors commented that they lack the experience in purchasing and maintaining PV systems, and that they have difficulties to distinguish high quality from bad quality hardware. Customs processes are considered cumbersome and challenging.
Digital Risk	This risk category has a low impact on financing costs. Interviewees are not concerned about cyber security or data protection. However, when planning with mobile payment services, ensuring good GSM coverage is crucial.
Labor Risk	This risk category has a high impact on financing costs. Investors agreed that there is a lack of skilled labor and the need to develop required skills through hands-on training programs for people in remote areas. Interviewees are sceptical about skill development in universities because university graduates would not go into the countryside to do simple engineering work, but would look for better-paid jobs and good infrastructure in urban areas.
Developer Risk	This risk category has a high impact on financing costs. Interviewees shared the view that no developers with experience and proven track record exist, and that it is difficult to find reliable information on potential project developers.
End-user Credit Risk	This risk category has a high impact on financing costs. The income level in rural areas in Cambodia is generally low. This lowers the households' ability to cope with unexpected cost events, which in turn can quickly lead to electricity payment default.
Financing Risk	This risk category has a high impact on financing costs. Investor pointed out that no domestic debt finance or aggregative financing models are available at the moment. One of the main challenges to receive a commercial loan are the high collateral requirements from domestic banks, which do not accept anything expect land and property titles (i.e. no project or other personal assets can be used).
Currency Risk	This risk category has a low impact on financing costs. The currency risk is considered low as the Cambodian Riel is pegged to the USD.
Sovereign Risk	This risk category has a medium impact on financing costs. Interviewees agreed that Cambodia has promising economic and social development prospects. Investors agreed that it is difficult for foreign investors to judge this risk reliably and that they are therefore often rather concerned about it. Domestic investors, on the other hand, are usually better informed and are, to some extent, even involved in governmental high-level discussions and feel more comfortable to predict sovereign-related risks.

7.2 Public instruments (Stage 2)

Selection and costing of public instruments

Having identified the key investment risks for solar-battery MG, a package of public instruments can be assembled to address them.

Table 26 at the end of this chapter sets out in full the stakeholders, barriers and risk categories for solar-battery MG in Cambodia and suggests a comprehensive list of matching public instruments to address these barriers and risks[110]. *Table 21* below provides a summary of that table and highlights selected public derisking instruments which specifically address the risk categories identified in the financing cost waterfalls above (*Figure 18*).

Table 21: Selection of public instruments to support investment into solar-battery MG in Cambodia

RISK CATEGORY	POLICY DERISKING INSTRUMENTS	FINANCIAL DERISKING INSTRUMENTS
Energy Market Risk	• National off-grid targets, tiered approach to statistics • **Build capacity of rural energy department, agencies and regulators** • **Establish dual-regulatory regime[111]** ◦ Light touch regime • Minimal self-registration ◦ Comprehensive regime: • Well-designed concessions • Regulated tariffs • Technical guidelines/standards for electricity quality • Technical guidelines/standards for grid expansion	• Comprehensive regime ◦ Grid expansion compensation scheme
Social Acceptance Risk	Public awareness campaigns	N/A
Hardware Risk	• Streamlined, consistent and facilitated customs procedures • Certification/technology standards for solar PV and energy efficient appliances	N/A
Digital Risk	**Well-designed telecom regulations enabling universal, competitive coverage and mobile money**	N/A
Labor Risk	Programs to develop a competitive, skilled labor market in solar-battery MG (all roles)	N/A
Developer Risk	Support to grow early-stage industry	N/A
End-user Credit Risk	• Facilitate growth of consumer credit data industry • Support productive use of electricity	Credit lines and loan guarantees to commercial banks lending to solar-battery MG developers
Financing Risk	• Strengthen capacities of domestic financial sector to facilitate increased investment in green infrastructure • Expand options for meeting collateral requirements for domestic lending to businesses • Strengthen domestic investors' familiarity with and capacity regarding solar-battery MG • Regulatory and tax reforms for asset backed securities	
Currency Risk	N/A[112]	N/A
Sovereign Risk	N/A	N/A

Source: modelling. See *Table 26* for a full description of these instruments. "N/A" indicates "Not Applicable". Bold text represents high-priority instruments.

[110] This table was derived from the generic public instrument table for renewable energy in the DREI report (UNDP, 2013). Based on stakeholder consultation and investors' feedback, a number of changes have been made to the generic table to align with the Cambodian-specific context. The table was then used as the basis for the DREI analysis for solar-battery MG in Cambodia, including the interviews with investors.

[111] The dual regulatory regime offers solar-battery MG developers the opportunity to conduct their business in one of two regulatory environments: (i) light-touch regulatory framework, with only minimal regulatory requirements, i.e. simple online self-registration, no tariff controls, no concession requirement, and only minimal reporting. However, under this regime, project developers do not receive exclusivity for a certain concession area and do not have access to government financial incentives; (ii) comprehensive regulatory framework; which operates under well-designed, exclusive concessions (e.g. size, years, targets) in determined areas, under regulated tariffs, technical standards and quality and reporting requirements. Project developers under this regime have also access to specific government financial incentives such as concessional loans or grant contributions.

[112] Not applicable because local currency is directly linked to USD

For solar-battery MG (illustrative building block targets of 10 MW[113] by 2025), the costs for public derisking instruments until 2025 are estimated at being USD 2.3 million for policy derisking instruments, at USD 5.1 million for financial derisking instruments and USD 2.9 million for direct financial incentives[114].

Investors provided further qualitative feedback. It is recognized that digitally-oriented models envisaged for solar-battery MGs in Cambodia are currently absent and that it will require significant, and coordinated public derisking measures to create a favorable investment environment. Investors identified three priority derisking measures: (i) strengthen capacities of existing government bodies or establish a government body or unit to advance/oversee/improve off-grid electrification; (ii) the implementation of a dual regulatory regime (comprehensive and light touch), including off-grid electrification areas and concessions; (iii) policies supporting digitalization, including cellular coverage in rural areas, and a competitive mobile money marketplace.

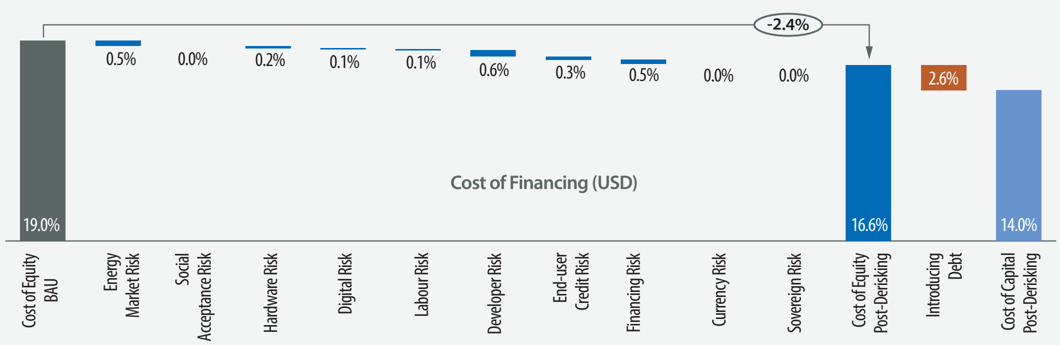
The full breakdown of each selected public instrument and its cost is provided in *Table 27*. Details of the assumptions and the methodology used to generate the cost estimates are available in Annex A.

Impact of public instruments on financing costs

The impact of the public instruments on reducing financing cost for solar-battery MG investments in Cambodia is illustrated in *Figure 19*. Based on the modelling analysis, the selected package of derisking instruments is anticipated to reduce the average cost of equity until 2025 by 2.4% down to 16.6%. Introducing debt to the financing structure[115], the total cost of capital decreases further by 2.6% to 14.0%.

A summary of the qualitative investor feedback on the public instruments discussed in the interviews and on their effectiveness in reducing financing cost for solar-battery MG in Cambodia is provided in *Table 22*.

Figure 19: Impact of public instruments on financing costs for solar-battery MG investments in Cambodia, post-derisking scenario



Source: interviews with investors; modelling; impacts shown are average impacts over the modelling period, assuming timing affects; results are blended for comprehensive and light-tough regulatory regimes

[113] 10 MW building blocks targets can be multiplied.

[114] The modelled direct financial incentives for solar-battery MG include a 10% grant financing component for total capital investment costs.

[115] No debt financing is anticipated in the business-as-usual scenario.

Table 22: Investor feedback on the effectiveness of public instruments to address solar-battery MG risk categories in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Energy Market Risk	All investors agreed that determining national off-grid electricity service areas for solar-battery MG and defining well-designed concessions for REEs is a powerful policy approach to tackle major investment concerns. This approach would also include providing long-term licenses aligned with solar-battery MG investment timelines and liberty in setting a cost-reflective tariff independently from the standard national grid tariff. Furthermore, investors regarded the proposed establishment of a regulatory approach with two co-existing regimes as very effective: one comprehensive regime (with licenses) for the medium and long term to increase investor's confidence and security; and a light touch regime for the short-term to start investments quickly.
Social Acceptance Risk	Although not regarded as crucial, developing and coordinating community impact and public awareness campaigns were rated as a very effective policy derisking instrument.
Hardware Risk	Quality assurance, warranties and after-sale-services by installer/manufacturers, as well as transparent and smooth custom procedures were highlighted as effective derisking solutions.
Digital Risk	As for SHS, where the use of GSM and mobile money is an integral part of the business model, interviewees agreed that well-designed telecom regulations on universal, competitive coverage and mobile money technologies (e.g. PAYG) are effective derisking measures. Other derisking instruments were not regarded as useful.
Labor Risk	Labor capacity development programs for solar-battery MG were considered moderately effective by interviewees. As for SHS, it was pointed out that if such programs were to be implemented, trainings would need to be designed for villagers in remote areas as it is where installation and maintenance work for solar-battery MG will be conducted.
Developer Risk	Interviewees agreed that a government-supported approach to improve information flows and network effects on solar-battery MG development would be an effective derisking measure.
End-user Credit Risk	Interviewees agreed that in the case for solar-battery MG, a direct financial incentive in form of a grant instrument to solar-battery MG operators bridging the gap between solar-battery MG generation cost and the national consumer grid tariff would be a highly effective way to ensure affordable solar-battery MG electricity tariffs, significantly reducing the end-user credit risk. Public loan guarantees or equity provision to mini-grid operators are regarded additional financial derisking approaches to reduce electricity tariffs and are not expected to be as effective as a grant instrument. In terms of policy derisking instruments, interviewees believe the following is essential to the solar-battery MG business case: the promotion of productive use of electricity e.g. through establishing networks of business development incubators and advisors providing training, and guidance covering mini-grid areas.
Financing Risk	Interviewees rated the proposed policy derisking instruments as very effective in enabling domestic debt finance and aggregating financing vehicles. In addition, a loan guarantee instrument by the government or an international development bank was suggested as an effective way to help solar-battery MG projects access domestic debt financing.
Currency Risk	Due to the generally low currency risk anticipation in Cambodia, the development of specific policy and financial derisking instruments was regarded not necessary by interviewees.
Sovereign Risk	Similar to solar rooftop PV and SHS, interviewees do not think that risk sharing products by development banks are an effective option for the solar-battery MG sector as they are only applicable for large project and project portfolios.

Source: interviews with investors (equity investors/developers and debt investors).

7.3. Levelized Cost (Stage 3)

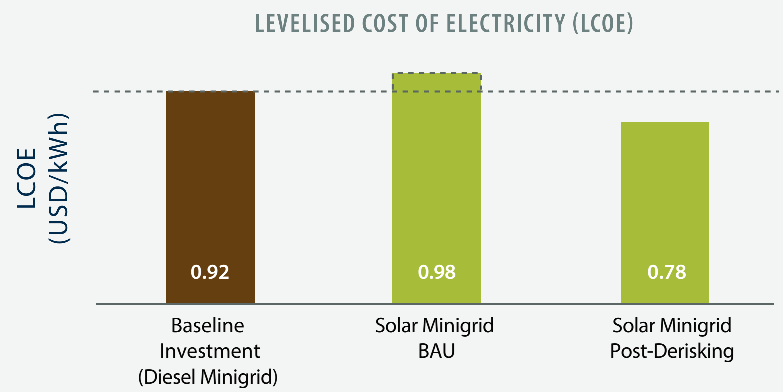
The levelized cost modelling compares today's financing costs with a post-derisking scenario with lower financing costs.

The results of the generation cost comparison, expressed through the LCOE, are illustrated in *Figure 20* below.

In the BAU scenario, solar-battery MG is slightly more expensive than the baseline. The baseline assumes the use of a diesel-based mini-grid. This approach results in baseline generation costs of USD 92 cents per kWh. In comparison, solar-battery MG energy costs in the BAU scenario is estimated at USD 98 cents per kWh. This means that electricity from solar-battery MG without derisking requires a slight price premium of USD 6 cents per kWh over the baseline energy technology mix.

For the post-derisking scenario, the cost of solar-battery MG falls to USD 0.78 cents per kWh. This is USD 14 cent lower than electricity costs in the diesel mini-grid baseline, indicating that when implementing government interventions to derisk the investment environment, electricity from solar-battery MG becomes more affordable than electricity from a diesel MG.

Figure 20: LCOEs for the baseline and solar-battery MG investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

7.4 Evaluation (Stage 4)

Performance Metrics

The model's performance metrics, evaluating the impact of derisking on the envisioned 2025 illustrative 10 MW building block target for solar-battery MG investment in Cambodia, are illustrated in *Figure 21*.

Each of the four performance metrics takes a different perspective in assessing the performance of the derisking instrument package.

- The **investment leverage ratio** illustrates the efficiency of public instruments in attracting investment, comparing the total cost of public instruments with the resulting private-sector investment.
- The **savings ratio** takes a social perspective, comparing the cost of derisking instruments deployed versus the economic savings that accrue to society from deploying the instruments.
- The **affordability** metric takes an electricity consumer perspective, comparing the generation cost in the post-derisking scenario with the original BAU scenario.
- The **carbon abatement** metric takes a climate change mitigation perspective, considering the carbon abatement potential and comparing the carbon abatement costs (the cost per tonne of CO_2 abated). This can be a useful metric for comparing carbon prices.

Please see Annex A (Stage 4 – Evaluation) for detailed explanations of the function and rational of each metric.

Taken as a whole, the performance metrics demonstrate how the deployment of public derisking instruments can make solar-battery MG a clean and economically sensible alternative to diesel mini-grids.

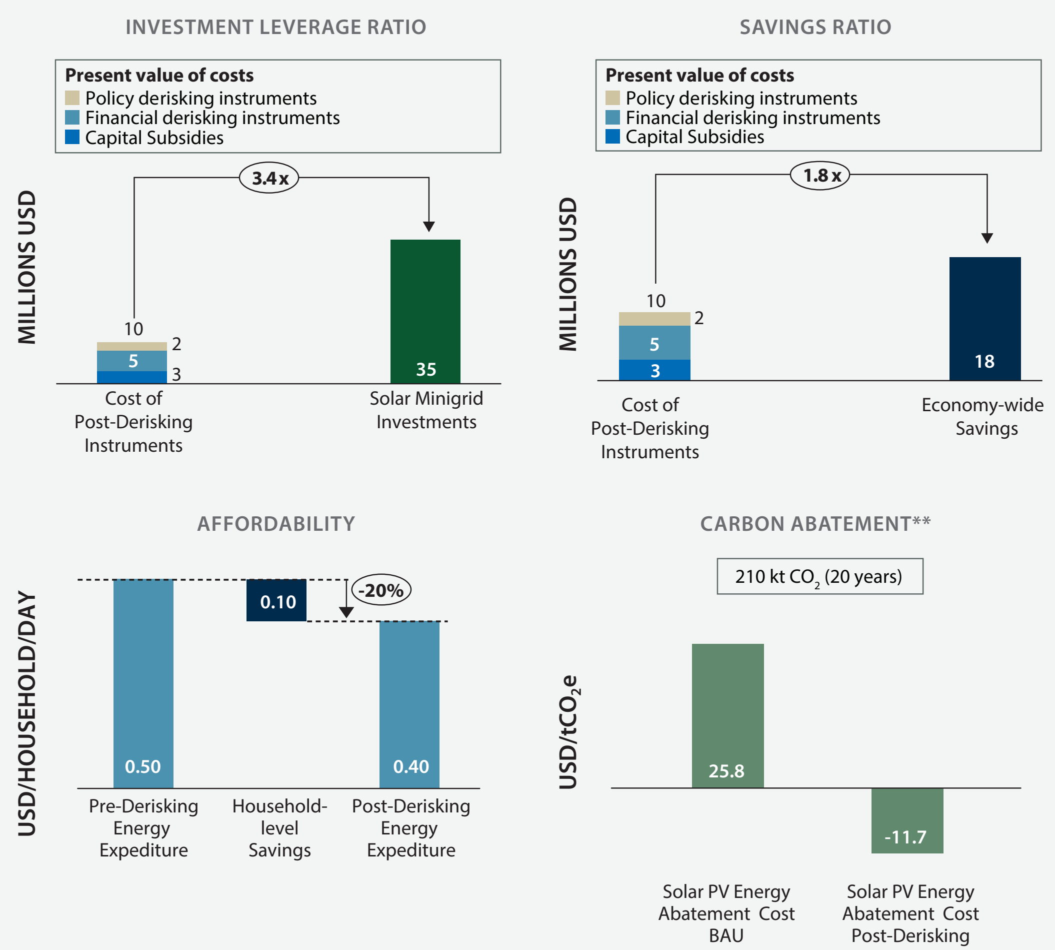
For instance, the affordability shows that derisking solar-battery MG investment can reduce the cost for rural households spent on electricity.

- In the BAU scenario (i.e. electricity generation through a diesel MG), a household spends USD 50 cent per day on electricity. In the post-derisking scenario for solar-battery MG, this cost falls to USD 40 cent per household per day, reducing the cost of energy spend for a household by 20%.

The other performance metrics illustrated in *Figure 21* reveal additional benefits of solar-battery MG derisking:

- for the leverage ratio, implementing a 10 MW-block in installed solar-battery MG capacity equates to USD 35 million in private sector investment. This results in a leverage ratio of 3.4x, i.e. the investments catalyzed are 3.4 times the amount spent on the public instruments;
- for economic savings, the derisking leads to economic savings of USD 18 million, leveraging the costs of derisking by 1.8;
- carbon abatement costs are reduced by 145% from USD 25.8 per tCO_2e to USD -11.7 per tCO_2e. The negative carbon abatement costs is due to the fact that post-derisking LCOE is lower than the LCOE of the diesel-fuel mini grid in the baseline.

Figure 21: Performance metrics for the selected package of derisking instruments in promoting a 10 MW building block of solar-battery MG investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2025 investment target may not be met.

** The Carbon Abatement metric can be broken down into the costs of policy derisking instruments, financial derisking instruments, the price premium and capital subsidies. While in the BAU scenario, the total of USD 25.8 per tCO_2e is due to the price premium, in the *post-derisking* scenario, this breakdown for the total of USD -11.7per tCO_2e is USD 10.7, USD 23.9, USD -60.0, and USD 13.7, respectively.

Sensitivities

A set of sensitivity analysis has been performed for solar-battery MG. The objective of performing the sensitivity analysis is to gain a better understanding of the robustness of the outputs and to be able to test different scenarios.

Three types of sensitivity analysis have been performed:

1. Key input assumptions
2. Achieving grid parity for solar-battery MG[116]
3. Different solar import tax exemption scenarios

1. Sensitivity analysis on key input assumptions

These have been performed for the following input assumptions: (i) investment costs; and (ii) financing cost (CoE and CoD). In addition, an additional analysis has been conducted, layering favorable and unfavorable input assumptions for solar-battery MG, creating an optimistic best-case, and a pessimistic worst-case scenario. The sensitivity analysis provide an indication of the degree to which each input parameter affects the outputs. In each case, all other assumptions have been kept constant[117]. The results for this type of sensitivity are summarized in *Table 23*.

Table 23: Solar-battery MG summary of LCOE outputs for sensitivity analysis on key input assumptions

<table>
<tr><th>TYPES OF SENSITIVITY</th><th>DESCRIPTION OF SENSITIVITY</th><th>BASELINE LCOE (USD/kWh)</th><th>BAU LCOE (USD/kWh)</th><th>POST-DERISKING LCOE (USD/kWh)</th></tr>
<tr><td>BASE CASE</td><td></td><td rowspan="8">0.92</td><td>0.98</td><td>0.78</td></tr>
<tr><td rowspan="2">INVESTMENT COSTS
(Base Case: 3.5 per Wp)</td><td>Higher investment costs: +20% (4.2 per Wp)</td><td>1.17</td><td>0.92</td></tr>
<tr><td>Lower investment costs: -20% (2.8 per Wp)</td><td>0.80</td><td>0.64</td></tr>
<tr><td rowspan="2">FINANCING COSTS
(Base Case: CoE: 19%, CoD: 11%)</td><td>Higher financing costs: 1% point (CoE: 20%, CoD: 12%)</td><td>1.02</td><td>0.80</td></tr>
<tr><td>Lower financing costs: 1% point (CoE: 18%, CoD: 10%)</td><td>0.95</td><td>0.75</td></tr>
<tr><td>LAYERED SENSITIVITIES – Best-case Scenario</td><td>Lower investment costs: -20% (2.8 per Wp)
Lower financing costs: 1% point
(CoE: 18%, CoD: 10%)</td><td>0.77</td><td>0.62</td></tr>
<tr><td>LAYERED SENSITIVITIES – Worst-case Scenario</td><td>Higher investment costs: +20% (4.2per Wp)
Higher financing costs: 1% point
(CoE: 20%, CoD: 12%)</td><td>1.19</td><td>0.95</td></tr>
</table>

[116] Applies to solar-battery MGs under the comprehensive and the light-touch regulatory regime.

[117] Note that keeping all other assumptions constant is a simplifying approach. For example, if higher capacity factors for solar PV are the result of improved solar modules (as opposed to improved solar PV sites), a different approach may be to also increase investment costs.

2. Achieving grid parity for solar-battery MG

In order to reach grid parity for solar-battery MG, two potential approaches were assessed:

1. Assuming that a large portion of the required financing is covered with highly concessional debt finance (80% of total financing needs; 2% interest rate). The analysis illustrated that grid parity cannot be achieved through this approach.

2. Introducing a grant element bridging the gap between the modelled LCOE of USD 78 cent per kWh in the post-derisking scenario and a USD 15 cent per kWh national consumer grid tariff[118]. The analysis illustrates that a total grant element of USD 20.5 million[119] over 7 years would be required to achieve grid parity for solar-battery MG (see *Table 24*).

Table 24: Solar-battery MG: achieving grid parity through grant financing

TYPES OF SENSITIVITY (USD)	DESCRIPTION OF SENSITIVITY	BAU LCOE (USD/kWh)	POST-DERISKING LCOE (USD/kWh)
Parity with grid-connected retail tariffs at 0.15/kWh	Providing grant financing to reach grid parity for solar-battery MG	0.78	0.15
	Grant finance required	20.5m	

3. Sensitivity analysis on solar import tax exemption scenarios

The report conducted a cost-benefit-analysis[120] of a solar import tax exemption instrument, modelling the below three scenarios:

1. Exemption of 10% import VAT on solar modules and inverters
2. Exemption of 35% import duties on inverters
3. Exemption of both 10% import VAT (solar modules and inverters) and 35% import duties (inverters)[121, 122]

118 The national consumer grid tariff ranges from USD 9.5-18.25 cents per kWh based on type of consumer (C&I, residential) and voltage (low, medium, high) (EAC, 2018). An average national consumer grid tariff of USD 15 cent per kWh has been assumed for rural households. Starting from 2019, there will be difference in tariffs applied for residential consumers for Phnom Penh and elsewhere (that are connected to national grid). For example, the tariffs of USD 9.5 cent/kWh is applicable for residents consume less than 10kWh per month while it should be USD12 cent/kWh for those consuming from 11-50 kWh per month, regardless of their locations. Tariffs for residents consuming more than 50 kWh per month is higher.

119 Total costs are split into USD 18.5 million for the comprehensive, and USD 2.0 million for the light-touch regulatory regime.

120 Costs and benefits are calculated over the investment lifetime of solar-battery MGs of 20 years. Costs represent foregone revenue for the government for not-collected import taxes on solar equipment; benefits represent the reduction of electricity costs for rural households. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that households can save more money through reduced electricity costs than can be earned through import taxes, making import tax exemption on solar PV equipment an economically viable instrument.

121 It is the author's understanding that an import VAT of 10% applies to all imported solar PV equipment, while specific import duties of 35% apply only for inverters and batteries (not for solar modules).

122 The combined modelling applied a multiplicative approach, i.e. the exemption of 35% on inverters and batteries was applied on the already reduced LCOE after reduction of 10% import VAT on solar modules, inverters and batteries.

The results are summarized in *Table 25*.

In summary, all three solar import tax exemption scenarios lead to net benefits over the lifetime of rooftop PV investments. The greatest benefit can be achieved by exempting both the VAT and import duties, estimated at net benefits of USD 9.1 million. Exempting solar duties alone (on inverters for rooftop PV) leads to net benefits of USD 6.5 million, while exempting the import VAT (on solar modules and inverters) result in net benefits of USD 3.2 million.

Table 25: Solar-battery MG: summary of a cost-benefit analysis on solar import tax exemption scenarios

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	COST[123] (USD)	BENEFITS (USD)	NET BENEFITS (USD)	LCOE (USD/kWh)
BASE CASE					0.78
SOLAR IMPORT TAX EXEMPTION	Exemption of 10% import VAT (on solar modules, batteries and inverters)	1.9m	5.1m	3.2m	0.74
	Exemption of 35% import duties on solar PV equipment (inverters and batteries)	3.2m	9.7m	6.5m	0.67
	Exemption of BOTH 10% import VAT and 35% import duties	4.8m	13.9m	9.1m	0.64

[123] Results refer to the post-derisking scenario, i.e.it is assumed that the solar import tax exemption takes effect in a derisked investment environment as modelled in this study.

Public Instrument Table for Solar-Battery MG

Table 26: The modelling exercise's public instrument table Solar-battery MG (Part I)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
1. Energy Market Risk	Risk arising from limitations and uncertainty in the energy market (off- and on-grid) regarding market outlook, access, price and competition	*Market outlook:* Lack of political will and/or uncertainty regarding national/state targets for electrification and renewable energy mini-grid investment
		Market access, competition and grid expansion: Limitations and inability, including due to government regulations, of mini-grid developers to access the electrification market; uncertainty regarding potential future competition in electrification; unclear, or lack of, grid planning and expansion policies
		Tariffs: Uncertainty or inflexibility in electricity tariff regulations for mini-grids
		Technical standards: Lack of clarity, uncertainty and/or inconsistent government technical requirements for mini-grids regarding (i) quality of service and (ii) grid integration, should it occur
		Competing subsidies: Competition from subsidised diesel and kerosene (mostly used for lighting); negative perceptions of mini-grid tariffs due to subsidised grid-distributed electricity

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Build political will and develop realistic and transparent targets, using multi-tier electrification indicators	Establish programmes to raise awareness and build political will with legislators (e.g., conferences, site visits, cross ministerial committees); establish/strengthen energy statistics office; pursue a tiered approach to statistics for electrification; perform initial resource inventory and mapping, including through spatial planning; formulate realistic and transparent targets by tier, technology and demographics; ongoing monitoring of statistics		
Establish regulatory approach with two, co-existing regimes: (i) light-touch (no license) and (ii) comprehensive (licensed). Mini-grid developers may choose to operate under either regime. Light-touch regime does not provide exclusivity, nor access to government financing or grants (see later risk categories).	**Light-touch regime (no license):** Establish simple mechanism for mini-grid developers to self-register and provide basic annual reporting; self-registered mini-grid developers have right-of-first-refusal for concessions under the comprehensive regime **Comprehensive regime (licensed):** Establish/develop capacity of institutions (e.g., rural electrification agency, regulator); determine national/state off-grid electricity service areas; define well-designed concessions (e.g, size, years, targets, bundling) for mini-grid developers; implement well-designed mechanism to grant exclusive concessions to mini-grid developers		**Comprehensive regime (licensed):** Establish compensation scheme (e.g., per kWh) in case of grid expansion
Establish co-existing (i) light-touch (no license) and (ii) comprehensive (licensed) approaches.	**Light-touch regime (no license):** No tariff controls. **Comprehensive regime (licensed):** Establish balanced and well-designed regulated tariffs to address monopoly risk, either through (i) tariff tables or (ii) price discovery, via auctions		
Establish co-existing (i) light-touch (no license) and (ii) comprehensive (licensed) approaches.	**Light-touch regime (no license):** Voluntary compliance with comprehensive regime standards. **Comprehensive regime (licensed):** Develop balanced technical standards/ requirements for quality of electricity and grid integration, with active enforcement		
Reform fossil fuel and grid-distributed electricity subsidies	Assessment of fuel and grid-distributed electricity subsidies; phase-out/down of subsidies*; awareness campaigns accompanying reform; design of transfer programs to vulnerable social groups		

* Note: This instrument can be/have elements of a direct financial incentive.

Table 26: The modelling exercise's public instrument table Solar-battery MG (Part II)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
2. Social Acceptance Risk	Risks arising from lack of awareness and resistance to renewable energy and minigrids in communities	Resistance by general public and local communities due to unfamiliarity with electricity and renewable energy sources; mis-information/perceptions and lack of awareness for mini-grid offerings; resistance from incumbent businesses (e.g., diesel based generation) and users (e.g., SHS), disrupted by mini-grids
3. Hardware Risk	Risk arising from limitations in the quality and availability of mini-grid hardware, as well as the customs treatment of hardware	*Quality of hardware:* Lack of access to information on quality, reliability (performance) and cost of hardware; lack of clarity or uncertainty regarding government technical standards to ensure safety of mini-grid hardware; lack of availability of warranties for components *Availability of hardware:* Lack of a competitive market for buying hardware (from both interenational and domestic suppliers); where appropriate, lack of locally tailored hardware *Customs:* Cumbersome customs/clearing process for importing hardware, leading to delays in delivery; punitively high customs tariffs on mini-grid hardware, particularly in comparison to other sectors
4. Digital Risk	Risks arising from use of cellular networks for remote monitoring and payments; the use of software; and abuse of consumer data	*Cellular networks and mobile money:* Lack of cellular coverage in rural areas, where electrification needed; over-dependence on a single operator for reliable cell service and payment processing; lack of mobile money, or limitations relating to fees on mobile money transactions *Software:* Limited standardization of software and interfaces on mini-grid developers' back-end data and operations, and mobile money payment platforms *Abuse of consumer data:* Possible abuse of consumer data privacy on payments and usage; lack of understanding/ clarity on uses of consumer information

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Develop and coordinate ongoing community impact and public awareness campaigns	Public awareness campaigns; stakeholder dialogues and workshops between policy makers, NGOs, communities, community leaders and end users		
Pilot models for community involvement	Piloting of community models such as revenue sharing or small equity stakes for households, plus employment prospects for individuals.		
Develop certification and standards for hardware; adopt internationally recognized standards and share best practices, where applicable	Transparently develop, update (as necessary), disseminate and enforce standards for technical performance and safety; mandate minimum warranties for components		
Ensure an open, competitive marketplace for buying hardware	Policy measures to ensure a competitive market for hardware availability; balanced industrial policy objectives, where applicable, for domestic manufacturers, with open markets for international manufacturers; government support for R&D into technical modifications to hardware to accommodate local conditions		
Streamlined and consistent customs procedures; reform of punitive custom tariff system	Reduction of customs administrative steps; public response timelines; effective and expedited recourse mechanisms. Full cost-benefit economic assessment and benchmarking of tariffs; phase-out/down of punitive customs tariffs; introduction of import tariff holidays and VAT exemptions*		
Well-designed telecom regulations enabling universal, competitive coverage and mobile money	Regulation on coverage areas and competition for cellular operators; regulations ensuring a competitive mobile money market, including reasonable fees for mobile money transactions		
Government support to form industry associations for standard-setting and sharing of best practices	Encourage engagement of MNOs, mobile money companies, mini-grid developers through industry associations, technology working groups to establish standards around he digitalization of energy services provision		
Institute balanced consumer data protection regulations	Facilitate the development of clear and transparent guidelines on data use by companies in the mini-grid ecosystem; raise awareness among consumers; government enforcement of data privacy laws		

* Note: This instrument can be/have elements of a direct financial incentive.

Table 26: The modelling exercise's public instrument table Solar-battery MG (Part III)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
5. Labour Risk	Risks arising from the lack of skilled and qualified potential employees	Lack of a competitive labor market of educated, skilled and qualified potential employees, leading to higher costs, hiring non-local staff and suboptimal performance
6. Developer Risk	Risks arising from limitations in the mini-grid operator's management capability, and its creditworthiness and cash flow.	*Management capability:* Lack of C-suite talent and experience to ensure effective execution (business planning, financial structuring, plant design (resource and demand assessment), installation, operations and maintenance), and to manage challenges (limited information, unforeseen events)
		Developer credit worthiness and cash flow strength: Inability of developer to secure low cost financing from investors due to lack of credit worthiness, or insufficient cash flows to meet investors' return requirements
7. End-user Credit Risk	Risk arising from customers' willingness, ability, and methods of payment for electricity	*Lack of information on end-user credit worthiness:* Lack of end-user credit data with which to assess the ability of end-users to pay for the initial connection fees, ongoing electricity bills and ancillary equipment (e.g., lights and appliances)
		Poor credit worthiness and non-payment: Risk of delayed, reduced or non-payment by customers due to poor credit worthiness, lack of funds available, electricity theft and social dynamics

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

<table>
<tr><th colspan="4">PUBLIC INSTRUMENTS</th></tr>
<tr><th colspan="2">POLICY DERISKING INSTRUMENTS</th><th colspan="2">FINANCIAL DERISKING INSTRUMENTS</th></tr>
<tr><th>ACTIVITY</th><th>DESCRIPTION</th><th>ACTIVITY</th><th>DESCRIPTION</th></tr>
<tr><td>Programmes to develop competitive, skilled labour market in renewable energy (all roles)</td><td>Apprenticeships, certificates and university programmes to build skills in renewable energy (e.g., engineering, marketing, business management)</td><td></td><td></td></tr>
<tr><td>Government support to improve information flows and network effects</td><td>Government support for establishing industry association; government support for initial industry conferences; dissemination of top-level, national resource assessment findings; government sponsored academic studies (e.g., on demand evolution)</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Public loans, guarantees and/or equity to mini-grid operators</td><td>Direct public loans to minigrid operator; public guarantees to commercial banks that are lending to the minigrid operator; public equity investments in minigrid operator</td></tr>
<tr><td>Facilitate growth of consumer credit data industry</td><td>Where applicable, government sponsored digital identity scheme; promotion of balanced privacy and financial regulations allowing for collection of credit data by the private sector; piloting of fintech solutions/platforms for credit data analysis</td><td></td><td></td></tr>
<tr><td>Facilitate end-user's ability to improve creditworthiness over time</td><td>Two complementary approaches:
(i) Facilitate access to consumer finance (e.g., government-sponsored digital ID scheme; general consumer finance reform; mobile money);
(ii) Support productive use of electricity (e.g, establish network of business development incubators and advisors providing training and guidance covering mini-grid areas)</td><td rowspan="2">Two possible approaches to address credit risk:
(i) Public loans, guarantees and/or equity to mini-grid operators
(ii) Government offtaker via PPA</td><td rowspan="2">(i) Direct public loans to mini-grid developer; public guarantees to commercial banks that are lending to the mini-grid developer; public equity investments in mini-grid developer
(ii) Government enters into PPA acting as an intermediary offtaker with mini-grid developer. Electricity is then onsold to end-users. This risk transfer/financial derisking approach can be combined with a per kWh subsidy* (direct financial incentive), addressing affordability concerns</td></tr>
<tr><td>Government mandates to ensure creditworthy anchor tenants for mini-grids</td><td>Government targets and mandates require creditworthy actors, both private (e.g., cell phone towers) and public (e.g., health centres), to obtain their electricity from renewable energy mini-grids</td></tr>
</table>

* Note: This instrument can be/have elements of a direct financial incentive.

Table 26: The modelling exercise's public instrument table Solar-battery MG (Part IV)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
8. Financing Risk	Risks arising from the lack of skilled and qualified potential employees	*Capital scarcity - liquidity constraints in domestic banking:* Limited availability of long term domestic loans due to high banking reserve requirements
		Capital scarcity - under-developed domestic financial sector: Low number of well-capitalised actors (debt, equity, insurance, pensions); lack of regulatory clarity on new types of financial products
		Capital scarcity - competing incentives/mandates: existing policies incentivise or mandate domestic financial sector (banks, pension funds) to invest in alternative, competing sectors to minigrids
		Limited domestic investor experience with minigrids: Lack of information, assessment skills and track-record for minigrid projects amongst domestic investor community; lack of network effects (investors, investment opportunities) found in established markets; lack of familiarity and skills with appropriate finance structures
9. Currency Risk*	Risks arising from currency mismatch between domestic currency revenues and hard currency financing	Uncertainty due to volatile local currency; unfavourable currency exchange rate movements resulting in domestic currency revenues not being sufficient to cover hard currency debt/equity servicing; inability to economically hedge FX exposure due to illiquid FX derivative markets
10. Sovereign Risk	Risk arising from a mix of cross-cutting political, economic, institutional and social characteristics in the particular country which are not specific to mini-grids	Limitations and uncertainty related to conflict, political instability, economic performance, weather events/natural disaster, legal governance, ease of doing business, crime and law enforcement, land tenure and infrastructure in the particular country

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)
* Note this risk category only applies if financing is in hard currency.

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Reform reserve requirements for domestic lending to businesses	Balanced approach to liquidity requirements, assessing trade-offs between financial stability and renewable energy/electrification objectives	Public loans, guarantees and/or equity to mini-grid operators to address capital scarcity	Direct public loans to mini-grid operators; public guarantees to commercial banks that are lending to mini-grid operators; public equity investments in mini-grid operators
Liberalise domestic financial sector	Liberalisation and introduction of competition into domestic financial sector; reforms to introduce and facilitate new types of finance (e.g., crowdfunding, peer-to-peer lending)		
Reform financial sector incentives for investing in specific sectors	Balanced approach to incentives across all sectors; introduce incentives, targets and mandatory lending requirements for renewable energy/minigrids/electrification		
Strengthen domestic investors' (debt and equity) familiarity with and capacity regarding renewable energy minigrids	Mini-grid/electrification finance dialogues and conferences; workshops/training for investors on project assessment and financial structuring		
Government support for long term development of liquid domestic FX derivative markets	Regulatory reforms enabling derivative trading for local securities exchanges; steering of large government FX hedging contracts to domestic FX markets.	Financial products to transfer some or all currency risk to public sector	Various design options exist. One option is the government entering into an intermediary PPA with minigrid operator, denominated in hard currency, and then onselling electricity to end-users at a fixed, or more stable, domestic currency tariff. Another option are government subsidised or facilitated F/X hedging programmes (particularly for illiquid F/X trades).
		Where applicable, risk sharing products by development banks to address political risk	Where applicable, provision of political risk insurance (PRI) covering (i) expropriation, (ii) political violence, (iii) currency restrictions, (iv) breach of contract

Summary Data Table

Table 27: Summary modelling assumptions for solar-battery MG in Cambodia[124]

SOLAR-BATTERY MG TECHNOLOGY	
2025 ElectrificationTarget (number of household connections)	49,075
Average Capacity Factor (%)	13.6%
Average System Size	
Solar PV (kW)	20.4
Battery (kWh)	65.4
Total Annual Serviced Demand (kWh)	11,912,113
Total System Size to Reach 2025 Target (kW)	10,005
BASELINE	
Baseline energy mix Diesel generator	100%
Average system size (kW)	11
Diesel Emission Factor (tCO_2e/MWh)	0.889
GENERAL COUNTRY INPUTS	
Effective Corporate Tax Rate (%)	20%
Public Cost of Capital (%)	8%

	PRE DERISKING SCENARIO	POST DERISKING SCENARIO		
FINANCING COSTS		Light-Touch	Comprehensive	Blended
Capital Structure				
Grants, as a % of total investment in generation and distribution assets	0%	10%	10%	
Equity/Debt structure of remaining investment	100%/0%	90%/0%	40%/50%	
Cost of Debt				
Concessional public loan	N/A	N/A	8.0%	
Commercial loans with public guarantees	N/A	N/A	9.7%	
Commercial loans without public guarantees	N/A	N/A	9.7%	
Loan Tenor				
Concessional public loan	N/A	N/A	10 years	
Commercial loans with public guarantees	N/A	N/A	10 years	
Commercial loans without public guarantees	N/A	N/A	10 years	
Cost of Equity	19.0%	17.8%	16.6%	
Weighted Average Cost of Capital (WACC) (After-tax, excl. grants)	19.0%	17.8%	14.0%	
INVESTMENT				
Total Investment (USD million, incl. grants)	$38,970,768	$3,897,007	$35,073,692	$38,970,768
Debt (USD million)				
Concessional public loan	N/A	N/A	$4,384,211	$4,384,211
Commercial loans with public guarantees	N/A	N/A	$2,192,106	$2,192,106
Commercial loans without public guarantees	N/A	N/A	$2,192,106	$2,192,106
Equity (USD million)	$38,970,768	$3,507,369	$22,797,900	$26,305,269
Grants/Capital Subsidies (USD million)	N/A	$389,708	$3,507,369	$3,897,077
COST OF PUBLIC INSTRUMENTS				
Policy Derisking Instruments (USD million, present value)				
Energy Market Risk Activities	N/A	$721,396	$1,466,777	$1,677,883
Social Acceptance Risk Activities	N/A	$209,180	$209,180	$209,180
Hardware Risk Activities	N/A	$10,591	$10,591	$10,591
Digital Risk Activities	N/A	$123,227	$123,227	$123,227
Labour Risk Activities	N/A	$8,202	$8,202	$8,202
Developer Risk Activities	N/A	$2,546	$2,546	$2,546
End-user Credit Risk Activities	N/A	$214,428	$214,428	$214,428
Financing Risk Activities	N/A	$26,391	$26,391	$26,391
Total	**N/A**	**$1,315,961**	**$2,061,342**	**$2,272,448**
Financial Derisking Instruments (USD million, present value)				
Energy Market Risk Instruments				
Compensation Scheme for Grid Extension	N/A	N/A	$3,532,058	$3,532,058
Developer Risk, End-user Credit Risk, and Financing Risk Instruments				
Public Loans*	N/A	N/A	$1,096,053	$1,096,053
Public Guarantees for Commercial Loans*	N/A	N/A	$438,421	$438,421
Currency/Macro Risk Instruments	N/A	N/A	N/A	N/A
Political Risk Instruments	N/A	N/A	N/A	N/A
Total	**N/A**	**N/A**	**$5,066,532**	**$5,066,532**
Direct Financial Incentives (USD million, present value)				
Grants/Capital subsidies	N/A	$289,852	$2,608,666	$2,898,518
Total	**N/A**	**$289,852**	**$2,608,666**	**$2,898,518**

* Please note that public loans and public guarantees for commercial loans address multiple risk categories at the same time, including developer risk, end-user credit risk, and financing risk.

[124] Initial solar-battery MGs are being installed or considered for installation in remote areas in Cambodia where the main grid will not reach in the near future (in line with the power development plan). Given the limited experiences so far, insufficient data is available on costs, performance, etc. in a Cambodian context. As such data on performance and costs from other countries is used and adjusted to the Cambodian situation as per feedback from stakeholders. When more solar-battery MGs have been installed, more data reflecting the Cambodian situation might become available.

Chapter 8

Off-Grid – Solar Home Systems Results

Off-Grid – Solar Home Systems Results

8

This chapter sets out the modelling results for SHS in Cambodia. The results present a set of cost-effective public derisking measures that allow meeting the study's illustrative SHS building block[125] of 10 MW by 2025. The results are organized in terms of the DREI methodology's four stages, as introduced in the previous Chapter 2 of this report.

8.1 Risk Environment (Stage 1)

Interviews

Data on the risk environment were obtained from 22 structured interviews held with domestic and international investors and project developers who are considering or are actively involved in on- and off-grid solar PV opportunities in Cambodia and the Southeast Asian region. These investors reflect a variety of interests, both strategic and financial.

Financing Cost Waterfalls

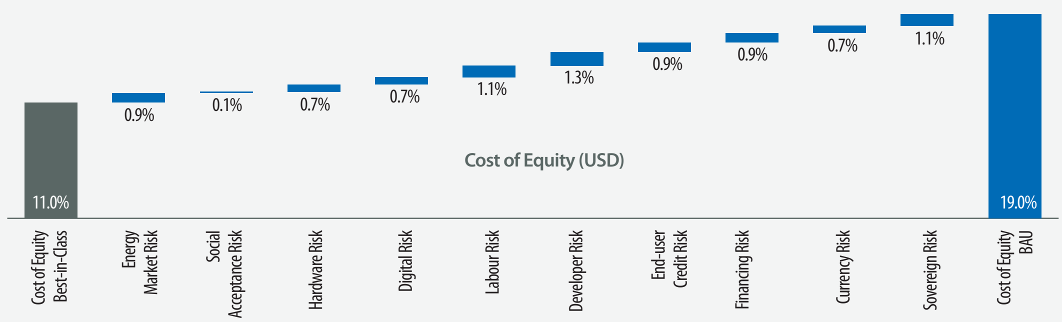
The analysis of the contribution of investment risks to higher financing costs for SHS in Cambodia is illustrated in the financing cost waterfall in *Figure 22*.

Based on data from interviews focusing on the risk environment of SHS it is estimated in this report that financing costs for SHS today are 19% for the CoE and 11% for the cost of debt CoD[126, 127]. These are substantially higher than in the best-in-class country estimates[128], which are at 11% CoE and 5% CoD. Financing costs for SHS, as for solar-batter MG, are also significantly higher than for on-grid solar PV in Cambodia, reflecting significant higher risk expectation for investments in off-grid solar PV.

Figure 22 illustrates how a range of investment risks currently contribute to higher financing costs for SHS[129]. The risk categories with a significant impact on elevated financing costs are (i) *energy market risk*; related to uncertainty on the market outlook and prices, and particular the lack of designated national off-grid electricity service areas and information on national grid extension plans; (ii) *developer risk*, related to the lack of high quality off-grid project developers with proven track record, and the absence of a centralised information platform on SHS developers; (iii) *labor risk*, due to a lack of skilled personnel for off-grid system installation and maintenance; (iv) *financing risk*, relating to the scarcity of capital from international and domestic markets; and (v) *end-user credit risk*, arising from the end-users ability and willingness to pay for electricity services.

[125] 10 MW building blocks targets can be multiplied.
[126] USD-denominated cost of equity and debt.
[127] The author assumed the same risk environment for both off-grid solar PV technologies.
[128] For SHS the author has applied a 'synthetic' best-in-class approach, where a synthetic best-in-class country was created.
[129] Only the impact on equity financing is shown for SHS as there is no debt financing anticipated in the business-as-usual scenario.

Figure 22: Impact of risk categories on financing costs for SHS investments in Cambodia, business-as-usual (BAU) scenario



(Source: interviews with rural electricity enterprises (REEs) and solar PV investors and developers; modelling: the author has applied a 'synthetic' best-in-class approach, where a synthetic (or imaginary) best-in-class country was created with data based on interviews and the authors' knowledge and expertise; see Annex A for details of assumptions and methodology.)

During the interviews, investors and project developers further provided qualitative feedback on the risk environment for SHS in Cambodia. A summary is provided in *Table 28*.

Table 28: Qualitative investor feedback on risk categories for SHS investment in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Energy Market Risk	This risk category has a high impact on financing costs. It has been positively noted that SHS development is being supported and that SHS is understood to have great potential to bring sustainable electricity access to the poor, and to rural areas. However, interviewees were concerned about project uncertainty due to the lack of designated national off-grid electricity service areas and information on the specific, geographical national grid extension plans. The arrival of the grid would remove the need for SHS as grid electricity would be available 24/7. Therefore, SHS is seen as an option only for really remote areas where grid extension is very unlikely to arrive in the foreseeable future, Also, the cost for electricity from SHS is significantly higher than the national grid, and some kind of financial support is likely to be required to make SHS affordable for people in rural areas (similar to ADB's REF program).
Social Acceptance Risk	This risk category has a low impact on financing costs. Interviewees shared the view that this is a low risk and that people in remote areas generally welcome SHS. However, some interviewees reported poor SHS experience due to technology failure leading to a rather negative perception of SHS. Other interviewees mentioned cases in which SHS provided reliable electricity for rural households and was therefore seen as favorable solution.
Hardware Risk	This risk category has a medium impact on financing costs. In a self-consumption approach, the quality of available SHS technology was mentioned as a potential issue due to the existence of an informal market offering low quality hardware and services. For a third-party ownership model, the investor will require very strict conditions on quality and performance standards from the technology provider.
Digital Risk	This risk category has a low impact on financing costs. Interviewees are not concerned about cyber security or data protection. However, when using mobile payment services, ensuring good GSM coverage is seen as crucial. Unlocking the IT systems of SHS was mentioned as a potential problem in the future, but technology providers usually integrate a sufficiently safe encryption technique to counter this.
Labor Risk	This risk category has a medium impact on financing costs. Investors agreed on a lack of skilled labor for SHS installation and maintenance. A few programs addressing the problem are already in place but should be extended. One investor explained that a major problem for him is that the installation/repair jobs are in the countryside, often without any infrastructure for accommodation or spare parts. Trained electricians prefer to work in the city and do not like to go back to the countryside. Trainings for villagers and people living in remote areas are considered key.
Developer Risk	This risk category has a high impact on financing costs. Interviewees shared the view that the SHS market is still small, that not many developers with experience and proven track record exist, and that it is difficult to find reliable and well-organized information on project developers.
End-user Credit Risk	This risk category has a high impact on financing costs. The income level in rural areas in Cambodia is generally low. This lowers the household's ability to cope with unexpected cost events, which in turn can quickly lead to electricity payment defaults.
Financing Risk	This risk category has a medium impact on financing costs. Investor pointed out that no domestic debt finance is available at the moment. All current SHS finance occurs in form of consumer finance via microfinance institutions, funded by Agence Française de Développement (AFD).
Currency Risk	This risk category has a low impact on financing costs. The currency risk is considered low as the Cambodian Riel is pegged to the USD.
Sovereign Risk	This risk category has a medium impact on financing costs.

8.2 Public instruments (Stage 2)

Selection and costing of public instruments

Having identified the key investment risks for SHS, a package of public instruments can then be assembled to address them.

Table 34 at the end of this chapter sets out in full the stakeholders, barriers and risk categories for SHS in Cambodia and suggests a comprehensive list of matching public instruments to address these barriers and risks[130]. *Table 29* below provides a summary of that table and highlights selected public derisking instruments which specifically address the risk categories identified in the financing cost waterfalls above (*Figure 22*).

Table 29: Selection of public instruments to support investment into SHS in Cambodia

RISK CATEGORY	POLICY DERISKING INSTRUMENTS	FINANCIAL DERISKING INSTRUMENTS
Energy Market Risk	• National off-grid targets, tiered approach to statistics • Build capacity of rural energy departments, agencies and regulators • Support a "light-touch", phased approach to regulation of SHS companies, with initial minimal self-registration	N/A
Social Acceptance Risk	• Public awareness campaigns • Enforcement of standards, outreach to community/community leaders	N/A
Hardware Risk	• Streamlined, consistent and facilitated customs procedures • **Certification/technology standards/guidelines for solar PV and energy efficient appliances**	N/A
Digital Risk	**Well-designed telecommunications regulations enabling universal, competitive coverage and mobile money**	N/A
Labor Risk	Programs to develop a competitive, skilled labor market in SHS (all roles)	N/A
Developer Risk	Support to grow early-stage industry	N/A
End-user Credit Risk	Facilitate growth of consumer credit data industry	Credit lines and loan guarantees to commercial banks' lending to SHS developers
Financing Risk	• Reform domestic financial sector to green infrastructure investment • Expand options for meeting collateral requirements for domestic lending to businesses • Strengthen domestic investors' familiarity with and capacity regarding SHS • Regulatory and tax improvements for asset-backed securities	
Currency Risk	N/A	N/A
Sovereign Risk	N/A	N/A

Source: modelling. See *Table 34* for a full description of these instruments. "N/A" indicates "Not Applicable". Bold text represents high-priority instruments.

[130] This table was derived from the generic public instrument table for renewable energy in the DREI report (UNDP, 2013). Based on stakeholder consultation and investors' feedback, a number of changes have been made to the generic table to align with the Cambodian-specific context. The table was then used as the basis for the DREI analysis for SHS in Cambodia, including the interviews with investors.

For SHS (illustrative building block targets of 10 MW[131] by 2025), the costs for policy derisking instruments until 2025 are estimated at USD 1.1 million, USD 0.5 million for financial derisking instruments and USD 1.2 million for direct financial incentives[132].

Overall, the SHS market is not regarded as risky as the solar-battery MG sector, consequently, less investment derisking is required. Enabling digital solutions for SHS remote controlling and ensuring broad, reliable and fast telecom coverage for pay-as-you-go mobile money are considered key in order to create an attractive investment framework for the private sector.

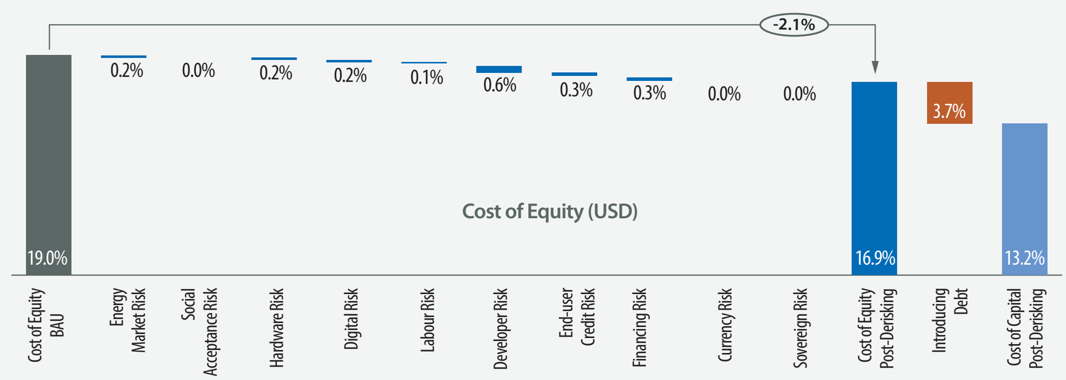
The full breakdown of each selected public instrument and its cost is provided in *Table 34*. Details of the assumptions and the methodology used to generate the cost estimates are available in Annex A.

Impact of public instruments on financing costs

The impact of the public instruments on reducing financing cost for SHS investments in Cambodia is illustrated in *Figure 23*. Based on the modelling analysis, the selected package of derisking instruments is anticipated to reduce the average cost of equity until 2025 by 2.1% down to 16.9%. When introducing debt to the financing structure[133], the total cost of capital decreases further by 3.7% to 13.2%.

A summary of the qualitative investor feedback on the public instruments discussed in the interviews and on their effectiveness in reducing financing cost for SHS in Cambodia is provided in *Table 30*.

Figure 23: Impact of public instruments on financing costs for SHS investments in Cambodia, post-derisking scenario



Source: interviews with investors; modelling; impacts shown are average impacts over the modelling period, assuming timing affects.

131 10 MW building blocks targets can be multiplied. A number of 10 MW units will be needed to achieve full improved electrification.

132 The modelled direct financial incentives for SHS include a 10% grant-financing component for total capital investment costs.

133 No debt financing is anticipated in the BAU scenario.

Table 30: Investor feedback on the effectiveness of public instruments to address SHS risk categories in Cambodia

RISK CATEGORY	INVESTOR FEEDBACK
Energy Market Risk	Interviewees scored the effectiveness of the proposed derisking package as very high. Priority should be given to clearly delineate off-grid service areas for SHS and support a "light-touch" phased approach to regulation of SHS companies. Developing national targets on solar PV is expected to provide more clarity on the off-grid electrification strategy and how Cambodia can meet its overall electrification target.
Social Acceptance Risk	Awareness campaigns on risk and opportunities of SHS (especially on where to find quality hardware and the need for maintenance) were considered an important and effective instrument to create a better understanding and higher acceptance of SHS[134].
Hardware Risk	Derisking instruments for hardware risk were rated moderately effective, with the development of certification and technology standards – and the enforcement of those standards – named as priority measure. Same as for the other solar PV technologies, clear and aligned custom processes for solar PV technology would be welcomed and were regarded as effective instruments.
Digital Risk	Interviewees agreed that well-designed telecommunications regulations enabling universal, competitive coverage and mobile money are effective derisking measures. Other measures were rated as moderately effective.
Labor Risk	Similar to the other solar PV sectors, programs to develop a skilled labor market for SHS were considered moderately effective. Different to the other solar PV technologies, SHS (and solar-battery MG) requires training for villagers and people living in remote areas as installation and maintenance work will be conducted in remote locations, and by local people.
Developer Risk	Interviewees shared the view that both (government) support to grow early-stage SHS industry and (government) support to support innovative financial aggregation vehicles are very effective approaches. Industry associations (e.g. SEAC) can share best practices among each other and other public and non-public actors, whereas financial aggregation models will be very important to enable the lease-to-own business model with SHS portfolio development.
End-user Credit Risk	Interviewees agreed that a direct financial incentive in form of a grant instrument to SHS project developers would be a highly effective way to reduce SHS lease fees, in turn reducing the end-user credit risk. Concessional credit lines to and public loan guarantees for domestic banks, which in turn would on-lend low cost debt to SHS lease-to-own project developers, are regarded as further financial derisking approaches to reduce lease fees for the end-user, and hence the end-user credit risk.
Financing Risk	Interviewees rated the proposed policy derisking instruments as very effective in enabling domestic debt finance and financial aggregation models. In addition, a loan guarantee instrument for domestic banks by the government or an international development bank was suggested as an effective way to help SHS projects access domestic debt financing.
Currency Risk	Due to the generally low currency risk anticipation in Cambodia, the development of specific policy and financial derisking instruments was regarded as not necessary by interviewees.
Sovereign Risk	Similar to solar rooftop PV and solar-battery MG, interviewees do not think that risk sharing products by development banks are an effective option for the SHS sector as they only are applicable for large projects and project portfolios.

Source: interviews with investors.

[134] For example the 'Good Solar Initiative' (www.goodsolarinitiative.org/about.html).

8.3 Levelized Cost (Stage 3)

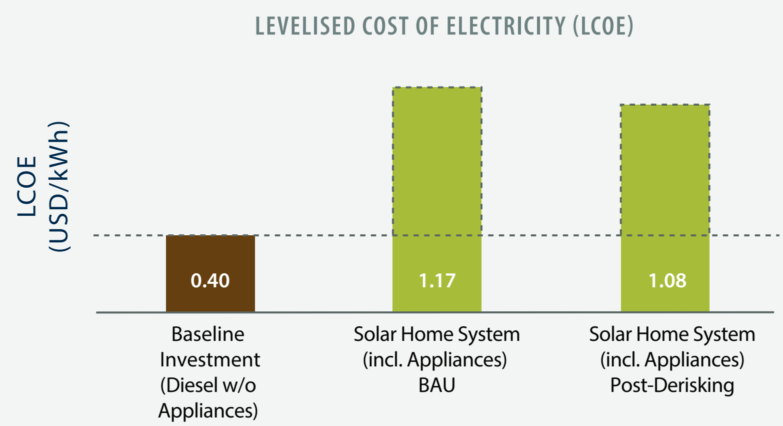
The levelized cost modelling compares today's financing costs with a *post-derisking* scenario with lower financing costs.

The results of the generation cost comparison, expressed through the LCOE, are illustrated in *Figure 24* below.

In the BAU scenario, SHS is more expensive than the baseline. The baseline assumes the use of diesel generators in village charging stations to charge rechargeable car batteries, which in turn supply low-voltage electricity for the households. This approach results in baseline generation costs of USD 0.40 per kWh. In comparison, SHS energy costs in the BAU scenario is estimated at USD 1.17 per kWh. This means that electricity from SHS without derisking requires a price premium of USD 0.77 per kWh over the baseline energy technology mix.

For the post-derisking scenario, the cost of electricity from SHS reduces slightly to USD 1.08 per kWh. This is USD 0.68 higher than electricity costs in the diesel generator baseline. This indicates that when implementing government interventions to derisk the investment environment, electricity from SHS becomes more affordable, but overall electricity costs from SHS remain significantly higher than electricity from the diesel generator baseline (from an electricity generation point of view). Households spend around USD 0.60 to 0.75 per charge, depending on size of battery, typically around 50-70 Ah. Charging frequency depends on energy needs of the household but is typically 1-3 times a week.

Figure 24: LCOEs for the baseline and SHS investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

8.4 Evaluation (Stage 4)

Performance Metrics

The model's performance metrics, evaluating the impact of derisking on the envisioned 2025 illustrative 10 MW building block target for SHS investment in Cambodia, are illustrated in *Figure 25*.

Each of the four performance metrics modelled for SHS takes a different perspective in assessing the performance of the derisking instrument package.

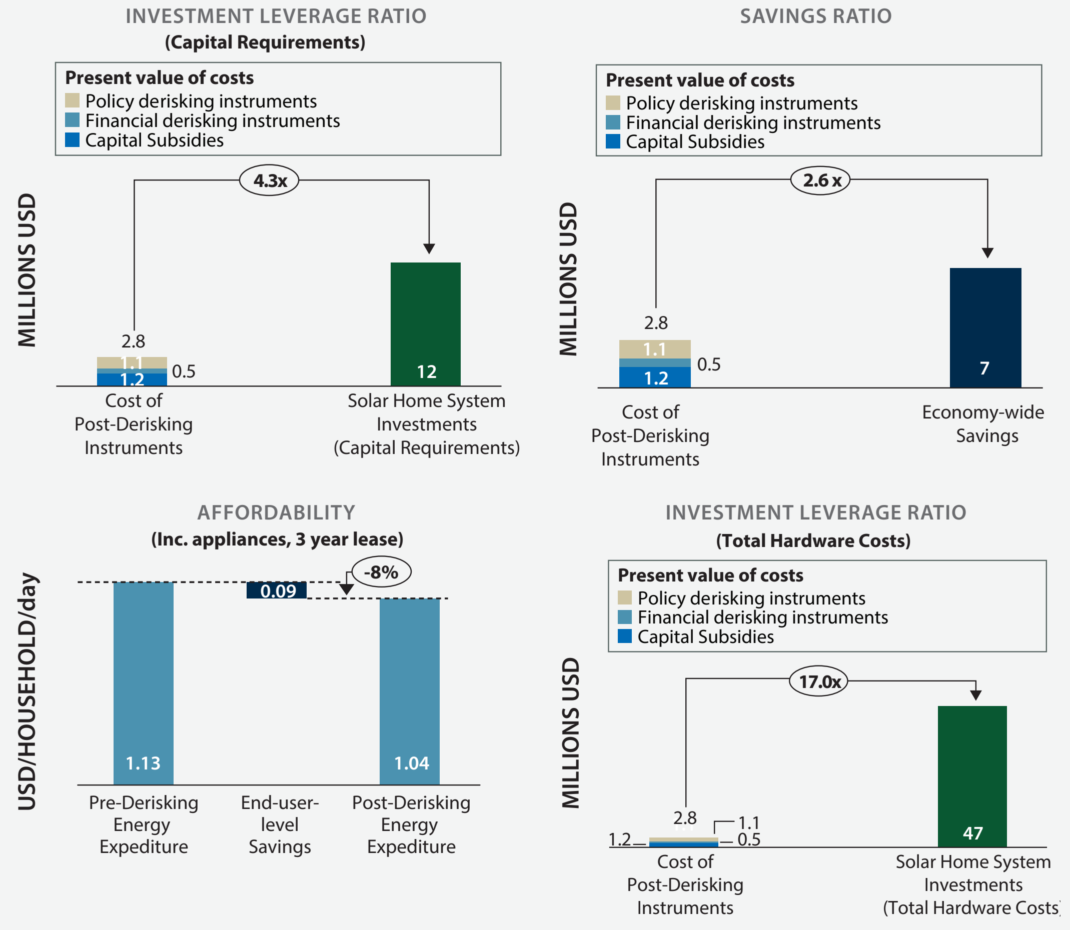
- The **investment leverage ratio** illustrates the efficiency of public instruments in attracting investment, comparing the total cost of public instruments with the resulting private-sector investment.
- The **savings ratio** takes a social perspective, comparing the cost of derisking instruments deployed versus the economic savings that accrue to society from deploying the instruments.
- The **affordability** metric takes an electricity consumer perspective, comparing the generation cost in the post-derisking scenario with the original BAU scenario.
- The **carbon abatement** metric takes a climate change mitigation perspective, considering the carbon abatement potential.

Please see Annex A (Stage 4 – Evaluation) for detailed explanations of the function and rational of each metric.

The performance metrics demonstrate how the deployment of public derisking instruments for SHS can lead to overall economic savings, leverage private sector investment in clean energy, reduce the electricity costs from SHS and avoid GHG emissions.

- For **investment leverage**, implementing a 10 MW-block in installed SHS capacity in a derisked environment equates to USD 12 million in private sector investment. This results in a leverage ratio of 4.3x, i.e. the investments catalyzed are 4.3 times the amount spent on the price premium in a non-derisked environment. Furthermore, a total of USD 47 million is leveraged for hardware investments over the entire 10-year SHS investment lifetime. This is due to the 3-year lease term business model, which effectively refinances hardware investments every three years.
- For **economic savings**, the derisking of the SHS environment leads to economic savings of USD 7 million, leveraging the costs of derisking by 2.6 (i.e. investment in derisking results in economic benefits 2.6x higher than the derisking costs).
- For **affordability**, public derisking reduces the average household spending on electricity per day by 8% from USD 1.13 to USD 1.04.
- For **emission reductions**, 140,000 tons of CO_2 will be avoided. Different to the other three solar-PV sub-sectors, no carbon abatement costs have been calculated for SHS. This is due to uncertainties related to technical and financial assumptions on the diesel-based battery charging stations in the baseline modelling.

Figure 25: Performance metrics for the selected package of derisking instruments in promoting one 10 MW building block of SHS investment in Cambodia



Source: modelling; see Annex A for details of assumptions and methodology.

* In the BAU scenario, the full 2025 investment target may not be met.

Sensitivities

A set of sensitivity analysis has been performed for SHS. The objective of performing the sensitivity analysis is to gain a better understanding of the robustness of the outputs and to be able to test different scenarios.

Two types of sensitivity analysis have been performed.

1. Sensitivity analysis on key input assumptions
2. Different solar import tax exemption scenarios

1. Sensitivity analysis on key input assumptions

These have been performed for the following input assumptions: (i) investment costs; (ii) lease term; and (iii) financing cost (CoE and CoD). The sensitivity analysis give an indication of the degree to which each input parameter affects the outputs. In each case, all other assumptions have been kept constant[135]. In addition, cumulative sensitivity scenarios have been modelled. These scenarios illustrate a best-case and worst-case scenario in which all three key input assumption are presumed either favorable or unfavorable for the SHS investment case. The results for this types of sensitivities are summarized in *Table 31*.

Highlights from the sensitivity analysis on key input assumptions:

- the leasing fees are very sensitive to changes in the lease term of the SHS project developer business model. Increasing the lease term from three to four years results in leasing fee reductions of USD 0.18 from USD 1.04 down to USD 0.86 per SHS unit per day and household. Decreasing the lease term to two years, leads to higher lease fees of USD 1.42 per SHS unit per day and household;

- when presuming throughout favorable investment assumptions in the cumulative sensitives scenario, daily energy costs for a household can be reduced by 35% from USD 1.04 to USD 0.68 in a derisked environment;

- when presuming throughout unfavorable investment assumptions in the cumulative sensitives scenario, daily energy costs for a household increase by 63% from USD 1.04 to USD 1.70 in a derisked environment.

Table 31: SHS summary of daily energy spend outputs for sensitivity analysis on key input assumptions

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	BAU DAILY ENERGY SPEND (USD/kWh)	POST-DERISKING DAILY ENERGY SPEND (USD/kWh)
BASE CASE		1.13	1.04
INVESTMENT COSTS (Base Case: 4.7 per Wp)	Higher investment costs: + 20% (5.6 per Wp)	1.34	1.23
	Lower investment costs: - 20% (3.8 per Wp)	0.92	0.85
LEASE TERM (Base Case: 3 years)	Longer lease term: +1 year (4 years)	0.94	0.86
	Shorter lease term: -1 year (2 years)	1.52	1.42
FINANCING COSTS (Base Case: CoE: 19%, CoD: 11%)	Higher financing costs: 1% point (CoE: 20%, CoD: 12%)	1.15	1.06
	Lower financing costs: 1% point (CoE: 18%, CoD:10%)	1.11	1.02
LAYERED SENSITIVITIES – Best-case Scenario	Lower investment costs: -20% (3.8 per Wp) Longer lease term: +1 year (4 years) Lower financing costs: 1% point (CoE: 18%, CoD: 10%)	0.75	0.68
LAYERED SENSITIVITIES – Worst-case Scenario	Higher investment costs: +20% (5.6 per Wp) Shorter lease terms: -1 year (2 years) Higher financing costs: 1% point (CoE: 20%, CoD: 12%)	1.83	1.70

135 Note that keeping all other assumptions constant is a simplifying approach. For example, if higher capacity factors for solar PV are the result of improved solar modules (as opposed to improved solar PV sites), a different approach may be to also increase investment costs.

2. Sensitivity analysis on solar import tax exemption scenarios

The report conducted a cost-benefit-analysis[136] of a solar import tax exemption instrument, modelling the below three scenarios:

1. Exemption of 10% import VAT on solar modules and inverters
2. Exemption of 35% import duties on inverters
3. Exemption of both 10% import VAT (solar modules and inverters) and 35% import duties (inverters)[137, 138]

The results are summarized in *Table 32*.

In summary, all three solar import tax exemption scenarios lead to net benefits over the lifetime of SHS investments. The greatest benefit can be achieved by exempting both the VAT and import duties, estimated at net benefits of USD 4.7 million. Exempting solar duties alone (on inverters for rooftop PV) leads to net benefits of USD 3.0 million, while exempting the import VAT (on solar modules and inverters) result in net benefits of USD 1.8 million.

Table 32: SHS: summary of a cost-benefit analysis on solar import tax exemption scenarios

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	COSTS[139] (USD)	BENEFITS (USD)	NET BENEFITS (USD)
Solar Import Tax Exemption	Exemption of 10% import VAT (on solar modules, batteries and inverters)	1.8m	3.6m	1.8m
	Exemption of 35% import duties on solar PV equipment (inverters and batteries)	3.4m	6.6m	3.0m
	Exemption of BOTH 10% import VAT and 35% import duties	4.9m	9.6m	4.7m

136 Costs and benefits are calculated over the investment lifetime of SHS of 10 years. Costs represent foregone revenue for the government for not-collected import taxes on SHS solar equipment; benefits represent the reduction of electricity costs for rural households. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that households can save more money through reduced electricity costs than can be earned through import taxes, making import tax exemption on solar PV equipment an economically viable instrument.

137 It is the author's understanding that an import VAT of 10% applies to all imported solar PV equipment, while specific import duties of 35% apply only for inverters and batteries (not for solar modules).

138 The combined modelling applied a multiplicative approach, i.e. the exemption of 35% on inverters and batteries was applied on the already reduced LCOE after reduction of 10% import VAT on solar modules, inverters and batteries.

139 Results refer to the post-derisking scenario, i.e.it is assumed that the solar import tax exemption takes effect in a derisked investment environment as modelled in this study.

Public Instrument Table for Solar-Battery MG

Table 33: The modelling exercise's public instrument table SHS (Part I)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
1. Energy Market Risk	Risk arising from limitations and uncertainty in the energy market (off- and on-grid) regarding market outlook, access, price and competition	*Market outlook:* Lack of political will and/or uncertainty regarding national/state targets for electrification and SHS
		Market access, competition and grid expansion: Limitations and inability, including due to government regulations, of SHS companies to access the electrification market; uncertainty regarding potential future competition in electrification
		Competing subsidies: lack of level playing field due to favorable treatment (fuel subsidies, tax, VAT, duties, guarantees) for grid distributed electricity (low tariffs), diesel and kerosene (mostly used for lighting)
2. Social Acceptance Risk	Risks arising from lack of awareness and resistance to SHS products and services in communities	Resistance by general public and local communities due to unfamiliarity, legacy poor-quality hardware, mis-information/perceptions and lack of awareness for SHS product offerings; resistance from incumbent businesses (e.g., diesel based generation, kerosene) disrupted by SHS
		Theft, tampering and vandalism of SHS equipment in local communities; differing norms of "ownership" within communities across cultures

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Build political will and develop realistic and transparent targets, using multi-tier electrification indicators	Establish programmes to raise awareness and build political will with legislators (e.g., conferences, site visits, cross ministerial committees); establish/strengthen energy statistics office, ensuring ongoing monitoring of statistics; pursue a tiered approach to statistics for electrification; perform initial resource inventory and mapping, including through spatial planning; formulate realistic and transparent targets by tier, technology and demographics;		
Clearly delineated off-grid service areas; support a "light-touch", phased approach to regulation of SHS companies	Determine transparent off-grid service areas; in near term, encourage self-registration of SHS companies and "light" reporting of activities in near term; in longer term, as SHS systems become more sophisticated, transition to a more regulated approach, with consumer protections legislation and agencies.		
Balanced treatment across sectors and reform of fossil fuel subsidies	Harmonized application of favored treatment across sectors; assessment of existing subsidies; phase-out/down of subsidies*; awareness campaigns accompanying reform; design of transfer programs to vulnerable social groups		
Develop and coordinate ongoing community impact and public awareness campaigns	Public awareness campaigns; stakeholder dialogues and workshops between policy makers, NGOs, communities, community leaders and end users		
Law enforcement, outreach to community/communicy leaders	Enforce penalties for those caught stealing, tamperign and/or vandalizing SHS equipment; reach out to community/tribe leaders to influence change of views within communities		

* Note: This instrument is a direct financial incentive.

Table 33: The modelling exercise's public instrument table SHS (Part II)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
3. Hardware Risk	Risk arising from limitations in the quality and availability of SHS hardware; issues arising from inefficiencies in the customs process; lack of standards in credit terms, leading to delays in delivery	*Quality of hardware :* Lack of access to information on quality, reliability (performance) and cost of hardware; lack of clarity or uncertainty regarding government technical standards to ensure safety of SHS hardware
		Availability of hardware: Where applicable, lack of an open market for buying hardware, including the availabilty from international suppliers
		Customs: Cumbersome customs/clearing process for importing hardware, leading to delays in delivery; lack of consistent enforcement of tariffs; where applicable, punitive customs tariffs
4. Digital Risk	Risks arising from use of cellular networks for remote monitoring and payments; the use of software; cyber security; and abuse of consumer data	*Cellular networks and mobile money:* lack of cellular coverage in rural areas, where electrification needed; over-dependence on a single operator for reliable cell service and payment processing; lack of mobile money, or limitations relating to fees on mobile money transactions
		Software: Limited standardization of software and interfaces on SHS companies' back-end data and operations, and mobile money payment platforms
		Cyber security: vulnerabilities of SHS companies and individual SHS to cyber attack, including unlocking of SHS
		Abuse of consumer data: possible abuse of consumer data privacy on payments and usage; lack of understanding/ clarity on uses of consumer information
5. Labour Inputs Risk	Risks arising from the lack of skilled and qualified potential employees	Lack of a competitive labour market of educated, skilled and qualified potential employees, leading to higher costs, hiring non-local staff and suboptimal performance

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Develop certification and standards for hardware; adopt internationally recognized standards and share best practices, where applicable	Collaborate with international/global certification agencies to establish minimum quality standards and required warranties; transparently develop, update (as necessary), disseminate, and enforce standards for technical performance and safety		
Ensure an open, competitive marketplace for buying hardware	Balance industrial policy objectives, where applicable, for domestic manufacturers, with open markets for international manufacturers		
Grovernent support to form industry associations	'Government support to form industry associations, working groups bringing together SHS companies to seek out better credit terms	Provision of working capital funds for early-stage SHS companies	
Streamlined and consistent customs procedures; balanced and considered approach to customs tariffs	Reduction of customs administrative steps; public response timelines; effective and expedited recourse mechanisms; consistent enforcement. Full cost-benefit economic assessment and benchmarking of tariffs; phase-out/down of punitive tariffs; introduction of import tariff holidays and VAT exemptions*		
Well-designed telecom regulations enabling universal, competitive coverage and mobile money	Regulation on coverage areas and competition for cellular operators; regulations ensuring a competitive mobile money market, including reasonable fees for mobile money transactions		
Government support to form industry associations	Encourage engagement of software companies, MNOs, mobile money companies through industry associations, technology working groups to establish standards around he digitalization of energy services provision		
Government cyber security initiatives	Government initiatives including establishing a cyber security entity, provding guidance and investigating incidents; promotion of cyber security insurance.		
Institute balanced consumer data protection regulations	Facilitate the development of clear and transparent guidelines on data use by companies in the SHS company ecosystem; raise awareness among consumers; government enforcement of data privacy laws		
Programmes to develop competitive, skilled labour market in SHS (all roles)	Apprenticeships, certificates and education programmes to build skills in SHS (engineering, installation, marketing, business management)		

* Note: This instrument is a direct financial incentive.

Table 33: The modelling exercise's public instrument table SHS (Part III)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
6. Developer Risk	Risks arising from limitations in the SHS Company's management capability, transparency in data and contractual terms, and its creditworthiness and cash flow.	*Management capability:* lack of C-suite talent and experience to ensure effective execution (business planning, service offering, securing financing, customer acquisition, distribution and installation, operations and maintenance), and to manage challenges (limited information, unforeseen events)
		Data transparency and contractual standardization: inability of SHS company to provide sufficient transparency on data/risk, and to generate a sufficient pipeline of standardized assets, to access innovative aggregative, low-cost financing (asset back securities)
		SHS company creditworthiness and cash flow strength: inability of SHS company to secure low-cost financing due to (i) lack of credit worthiness or (ii) insufficient cash flow and/or pipeline of quality receivables
7. Payment and Credit Risk	Risk arising from customers' willingness and ability to pay for electricity/energy service	*Information on end-user credit worthiness:* Lack of end-user credit data with which to assess the ability of end-users to pay for the downpayment on SHS products, and ongoing electricity bills

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

PUBLIC INSTRUMENTS			
POLICY DERISKING INSTRUMENTS		FINANCIAL DERISKING INSTRUMENTS	
ACTIVITY	DESCRIPTION	ACTIVITY	DESCRIPTION
Government support to grow early-stage industry	Government support for establishing industry association; government support for initial industry conferences; dissemination of top-level, national resource assessment findings; government sponsored academic studies (for example, on-demand evolution)		
Government support to promote innovative aggregative finance	Government support, via industry associations, to coordinate stakeholders (e.g., SHS companies, financial intermediaries, investors) on industry-wide recommendations for best practice standardized data sets (KPIs) and contractual terms		
		Public loans, guarantees and/or equity to SHS companies and/or aggregative financing	Public loans to SHS companies; public guarantees to commercial banks lending to SHS companies, and to investors in aggregative SPVs for SHS companies; public equity investments in SHS companies; currency and concessionality of products may vary
Facilitate growth of consumer credit data industry	Where applicable, government sponsored digital identity scheme; promotion of balanced privacy and financial regulations allowing for collection of credit data by the private sector; piloting of fintech solutions/platforms for credit data analysis		
Facilitate end-user's ability to improve creditworthiness over time	Facilitate access to consumer finance (e.g., government-sponsored digital ID schemes; general consumer finance reform; mobile money)	Public loans, guarantees and/or equity to SHS companies	Direct public loans to SHS companies; public guarantees to commercial banks that are lending to SHS companies, and to investors in aggregative SPVs for SHS companies; public equity investments in SHS companies; currency and concessionality of products may vary

* Note: This instrument is a direct financial incentive.

Table 33: The modelling exercise's public instrument table SHS (Part IV)

BARRIERS		
RISK CATEGORY	**DESCRIPTION**	**UNDERLYING BARRIERS**
8. Financing Risk	Risks arising from scarcity of domestic investor capital (debt and equity) for SHS companies, and domestic investors' lack of familiarity with SHS and appropriate financing structures	*Capital scarcity - under-developed domestic financial sector:* Low number of financial actors (debt, equity, insurance, pensions)
		Capital scarcity - liquidity constraints in domestic banking: Limited availability of long term domestic loans due to high banking reserve requirements
		Capital scarcity - competing incentives/mandates: Domestic financial sector (banks, pension funds) mandated to invest in alternative, competing sectors
		Capital scarcity - aggregative financing models: Lack of regulatory and tax clarity on aggregative models, such as asset backed securities;
		Limited domestic investor experience with SHS, including aggregative financing models: Lack of information, assessment skills and track-record for SHS companies amongst domestic investor community; limited/lack of financial intermediaries and advisors; lack of network effects (investors, investment opportunities) found in established markets; lack of famliarity with SPV, warehouse vehicle legal structures; lack of awareness on pricing for aggregative financing models
9. Currency Risk*	Risks arising from currency mismatch between hard currency debt/equity and domestic currency revenues	Uncertainty due to volatile local currency; unfavourable FX rate movements resulting in domestic currency not being sufficient to cover debt/equity servicing; inability to economically hedge FX exposure due to illiquid FX derivative markets.
10. Sovereign Risk	Risk arising from a mix of cross-cutting political, economic, institutional and social characteristics in the particular country which are not specific to SHS	Limitations and uncertainty related to conflict, political instability, economic performance, weather events/natural disaster, legal governance, ease of doing business, crime and law enforcement, and infrastructure in the particular country

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

* Note this risk category only applies if financing is in hard currency.

<table>
<tr><th colspan="4">PUBLIC INSTRUMENTS</th></tr>
<tr><th colspan="2">POLICY DERISKING INSTRUMENTS</th><th colspan="2">FINANCIAL DERISKING INSTRUMENTS</th></tr>
<tr><th>ACTIVITY</th><th>DESCRIPTION</th><th>ACTIVITY</th><th>DESCRIPTION</th></tr>
<tr><td>Liberalise domestic financial sector</td><td>Liberalisation and introduction of competition into domestic financial sector</td><td rowspan="5">Public loans, guarantees and/or equity to SHS companies</td><td rowspan="5">'Direct public loans to SHS companies; public guarantees to commercial banks that are lending to SHS companies, and to investors in aggregative SPVs for SHS companies; public equity investments in SHS companies; currency and concessionality of products may vary</td></tr>
<tr><td>Reform reserve requirements for domestic lending to businesses</td><td>Balanced approach to liquidity requirements, assessing trade-offs between financial stability and renewable energy/electrification objectives</td></tr>
<tr><td>Reform financial sector incentives for investing in specific sectors</td><td>Balanced approach to incentives across all sectors; introduce incentives, targets and mandatory lending requirements for renewable energy/SHS/electrification</td></tr>
<tr><td>Regulatory and tax framework for aggregative financing models</td><td>Regulatory and tax reforms for asset backed securities for SHS</td></tr>
<tr><td>Strengthen domestic investors' (debt, equity, institutions, intermediaries) familiarity with and capacity regarding SHS and aggregative financing models</td><td>SHS/electrification finance dialogues, events and conferences; sharing of successful deal structures; transparent data on pricing of financial products; workshops/training for investors on SHS assessment and innovative financial structuring</td></tr>
<tr><td>Regulatory reforms enabling derivative trading for local securities exchanges; steering of large government FX hedging contracts to domestic FX markets.</td><td>Financial products to transfer currency risk to public sector</td><td>Government subsidised or facilitated F/X hedging programmes for SHS companies</td><td>Various design options exist. One option is the government entering into an intermediary PPA with minigrid operator, denominated in hard currency, and then onselling electricity to end-users at a fixed, or more stable, domestic currency tariff. Another option are government subsidised or facilitated F/X hedging programmes (particularly for illiquid F/X trades).</td></tr>
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Summary Data Table

Table 34: Summary modelling assumptions for SHS in Cambodia

SHS	
2025 ElectrificationTarget (number of household connections and SHS units installed)	100,000
Generation Capacity of one SHS unit	100
Lease term (years)	3
Product Life (years)	10
BASELINE	
Baseline energy mix	
Diesel generator	100%
Average system size (kW)	10
Grid Emission Factor (tCO_2e/MWh)	0.889
GENERAL COUNTRY INPUTS	
Effective Corporate Tax Rate (%)	20%
Public Cost of Capital (%)	8%

	PRE-DERISKING	POST-DERISKING
FINANCING COSTS		
Capital Structure		
Equity Financing Breakdown		
Commercial Equity	100%	87%
Impact Equity	0%	0%
Grant Equity	0%	13%
Debt Financing Breakdown		
Public Loans	0%	50%
Commercial Loans w/ Public Guarantees	0%	25%
Commercial Loans w/o Public Guarantees	0%	25%
SPV Debt	0%	0%
Cost of Equity		
Commercial Equity	19.0%	16.9%
Impact Equity	N/A	N/A
Grant Equity	N/A	0.0%
Cost of Debt		
Concessional public loan	N/A	8.0%
Commercial loans with public guarantees	N/A	9.7%
Commercial loans without public guarantees	11.0%	9.7%
Weighted Average Cost of Capital (WACC) (After-tax)	19.0%	14.5%
INVESTMENT		
Total Investment Needs (USD million)	$11,239,582	$11,895,494
Equity (USD million)		
Commercial Equity	$11,239,582	$7,732,071
Impact Equity	$0	$0
Grant Equity	$0	$1,189,549
Debt (USD million)		
Concessional public loan	$0	$1,486,937
Commercial loans with public guarantees	$0	$743,468
Commercial loans without public guarantees	$0	$743,468
COST OF PUBLIC INSTRUMENTS		
Policy Derisking Instruments (USD million, present value)		
Energy Market Risk Instruments	$0	$681,891
Social Acceptance Risk Instruments	$0	$209,180
Hardware Risk Instruments	$0	$10,591
Digital Risk Instruments	$0	$123,227
Labour Risk Activities	$0	$8,202
Developer Risk Activities	$0	$2,546
End-User Credit Risk Instruments	$0	$16,906
Financing Risk Activities	$0	$26,391
Total Cost of Policy Derisking Instruments	**$0**	**$1,078,934**
Financial Derisking Instruments (USD million, present value)		
Equity Products		
Political Risk Insurance for Equity Investment	$0	$0
Debt Products		
Public Loans	$0	$371,734
Commercial Loans with Guarantees	$0	$148,694
Total Cost of Financial Derisking Instruments	**$0**	**$520,428**

Source: authors, adapted from Derisking Renewable Energy Investment (UNDP, 2013)

Chapter 9

Conclusions and Next Steps

Conclusions and Next Steps

9

Table 35 below provides a comprehensive overview of the modelling results across all four solar PV sub-sectors analyzed in this report.

Table 35: Summary of modelling results across all four solar PV sub-sectors (all costs in USD)

PARAMETER		UTILITY-SCALE PV	ROOFTOP PV[140]	SOLAR-BATTERY MG	SOLAR HOME SYSTEMS
Targeted Installed Capacity		350 MW	350 MW	10 MW	10 MW
Target Year		2030	2030	2025	2025
Total Investment Costs (Capital)		280m	339m	35m	12m
Total Investment Costs (Hardware)		N/A	N/A	N/A	47.5m[141]
Hardware Costs		0.8/Wp	0.9/Wp	3.5/Wp	12.0/Wp
LCOE (Utility-scale, Rooftop PV)/Daily Energy Spend (MG, SHS	Pre-Derisking	0.105/kWh	0.135/kWh	0.50/hh/day	1.13/hh/day
	Post-Derisking	0.087/kWh	0.101/kWh	0.40/hh/day	1.04/hh/day
Cost – Policy Derisking Instruments (USD)		6.4m	7.2m	2.3m	1.1m
Cost – Financial Derisking Instruments (USD)		32.8m	8.6m	5.1m	0.5m
Cost – Direct Financial Incentives (USD)		N/A	N/A	2.9m	1.2m
Financing Cost – Cost of Equity	Pre-Derisking	15.0%	17.0%	19.0%	19.0%
	Post-Derisking	12.0%	14.5%	16.7%	16.9%
Financing Cost – Cost of Debt	Pre-Derisking	9.0%	10.0%	11.0%	11.0%
	Post-Derisking	6.7%	8.4%	9.7%	9.7%
Capital Structure – Pre-Derisking		Debt: 50% Equity: 50%	Debt: 25% Equity: 75%	Debt: 0% Equity: 100%	Debt: 0% Equity: 100%
Capital Structure – Post-Derisking		Debt: 75% Equity: 25%	Debt: 75% Equity: 25%	Debt: 50% Equity: 50%	Debt: 50% Equity: 50%
Carbon Abatement		5.5 mtCO_2e	2.8 mtCO_2e	210 ktCO_2e	140 ktCO_2e

Overall, Cambodia has the potential to attract significant private sector investment in solar PV, totalling USD 903 million[142] across the four solar PV sub-sectors to achieve the report's targets. The total public cost of derisking and financial incentives is estimated at USD 68 million[143, 144], leading to USD 146 million in economic savings, resulting in significant improvements in affordability and emission reductions of over 8.7 million tonnes of CO_2 over 25 years[145].

[140] The overall investment target for rooftop PV of 350 MW has been divided equally into 175 MW in the commercial and industrial (C&I) sector and 175 MW in the residential sector. Except for the total capital investment costs, the report's modelling is solely performed on rooftop PV for the C&I sector and does not further refer to the residential sector.

[141] A total of USD 47.5 million is leveraged for hardware investments over the entire 10-year SHS investment lifetime. Due to the 3-year lease term business model, which effectively refinances hardware investments every three years, the actual capital need for SHS project developers is USD 12 million.

[142] The overall private sector investment potential comprises the total capital and hardware investments costs across all sub-sectors and assumes six 10 MW off-grid investment blocks for solar-battery MG and SHS (three for solar-battery MG and three for SHS). The number of assumed off-grid investment blocks addresses the non-grid connected market. If the non-grid connected market is excluded, i.e. only one solar-battery MG and one SHS building block is assumed, the overall private sector investment potential is USD 714 million.

[143] Includes direct financial incentives for off-grid sources.

[144] Total public cost of derisking measures and financial incentives, total economic savings and total emission reductions assume the realization of 350 MW utility-scale PV, 175 MW rooftop PV (C&I only), 1 x 10 MW solar-batter MG builidng block, and 1 x 10 MW SHS building block.

[145] These 8.7 million tonnes of CO_2 are equivalent to Cambodia's annual CO_2 emissions from energy use (WRI 2018).

For on-grid, solar PV can assist Cambodia in meeting its growing power demand and improving its energy security, including reducing seasonal imports. Following recent initial investments and policies, Cambodia can implement further derisking measures to scale-up investment. In utility-scale PV, a main objective can be to put in place a fully competitive, transparent and regulated market. In rooftop PV, the opportunity is to expand the recent regulations to residential and small-business sectors and consider revising the recently introduced solar capacity charge in order to create a balanced level-playing field with other technologies.

For off-grid, the report assumes new, private sector, digitally-oriented models for both solar-battery MGs and PAYG SHS. These new models are promising, having demonstrated rapid levels of investment in other countries, in particular in East Africa and India. Derisking measures will likely need to be phased, as each sub-sector evolves and matures. The modelling assumes direct grant subsidies will be required, given the early-stage of each sub-sector and the public-good nature of electrification.

This report is neutral between the two sub-sectors and recommends that the selection of technologies is based on further geo-spatial modelling and other considerations:

- solar-battery MGs are suited to more dense populations, offer the potential for productive use and higher generation capacity, but also require well-designed regulations.
- PAYG SHS are suited to dispersed end-users. SHS appears to need minimal regulatory support, at least in early phases of market development.

Promoting investment in each solar PV sub-sector will require the implementation of its specific package of derisking measures, as set out in the report. At the same time, there are commonalities across sectors and the opportunity to create efficiencies via derisking measures that address multiple sub-sectors at once.

Three areas of public derisking measures have benefits across all sub-sectors:

1. supporting, via training and certification, a high-quality private sector workforce in solar PV, including technical staff, and engineering, procurement and construction (EPC) contractors

2. supporting, for example via early financial aid to industry associations, a competitive domestic market in private sector developers in solar PV

3. reform the domestic financial sector, to support lending and low-cost financing for RE in local currency.

4. developing official RE and solar PV targets to clarify investment potential and national grid integration requirements

A set of sensitivity analysis has been performed for each of the four solar PV sub-sectors, with the objective to gain a better understanding of the robustness of the modelling outputs. Sensitivity analysis on key input assumptions[146] and on the impact of carbon pricing on the baseline energy scenario illustrated that generation costs are sensitive to key assumptions.

For example, when assuming an optimistic scenario in which favorable conditions for rooftop PV occur simultaneously, a generation cost as low as USD 5 cent can be achieved in Cambodia. Please see individual solar PV sub-sector chapters for detailed results of the sensitivity analysis.

[146] Analyzed input assumptions include investment costs, solar capacity factor, financing costs and lease term (for SHS only).

In addition, a cost-benefit-analysis[147] on different solar PV import tax exemption scenarios illustrates that significant net-benefits can be achieved over investment lifetimes in all four analyzed solar PV sub-sectors (see *Table 36*). The greatest benefits can be achieved in the rooftop PV sub-sector where the high share of solar module and inverter costs relative to the total investment costs (82%) make this instrument particular effective. Solar-battery MGs would also benefit strongly due to tax exemption on batteries which represent a large share of overall investment costs. Across all four sub-sectors, when both VAT and import duties on hardware are waived, total net benefits of USD 35 million in economic savings can be achieved.

Table 36: summary of cost-benefit-analysis for solar PV import tax exemption across solar PV sub-sectors

TYPES OF SENSITIVITY	DESCRIPTION OF SENSITIVITY	COST[148] (USD)	BENEFITS (USD)	NET BENEFITS (USD)
Exemption of 10% import VAT (on solar modules and inverters)	UTILIYT-SCALE PV	10.6m	14.9m	4.3m
	ROOFTOP PV	7.0m	18.5m	11.5m
	SOLAR-BATTERY MG	1.9m	5.1m	3.2m
	SHS	1.8m	3.6m	1.8m
Exemption of 35% import duties on solar PV equipment (only inverters and batteries)	UTILIYT-SCALE PV	5.0m	7.1m	2.1m
	ROOFTOP PV	2.7m	7.2m	4.5m
	SOLAR-BATTERY MG	3.2m	9.7m	6.5m
	SHS	3.4m	6.6m	3.0m
Exemption of BOTH 10% import VAT and 35% import duties	UTILIYT-SCALE PV	13.4m	18.8m	5.4m
	ROOFTOP PV	9.5m	25.1m	15.6m
	SOLAR-BATTERY MG	4.8m	13.9m	9.1m
	SHS	4.9m	9.6m	4.7m

Next Steps

In order to build consensus and political action, the analysis and findings in this report can be further discussed and developed among government agencies and other key stakeholders. The intent of this report is not to provide a predominant result, but to provide transparent findings, inputs and assumptions, so that they can contribute to an informed design process.

The report identifies a number of possible follow-up modelling and research steps to deepen the technical analysis.

[147] Costs and benefits are calculated over the investment lifetime of the asset. Costs represent foregone revenue for the government for not-collected import taxes on solar equipment; benefits represent the reduction of generation costs through reduced investment costs (for utility-scale and rooftop PV) or reduced electricity costs for rural households (solar-battery MG and SHS) due to the tax exemption. Net benefits are calculated by comparing costs and benefits. A net benefit indicates that the reduction in electricity generation costs is higher, or that households can save more money through reduced electricity costs, than the potential revenue from import, making import tax exemption on solar PV equipment an economically viable instrument.

[148] Results refer to the post-derisking scenario, i.e. it is assumed that the solar import tax exemption takes effect in a derisked investment environment as modelled in this study.

Should Cambodia wish to advance immediately with solar PV, Cambodia can proceed with the following for each of the four sub-sectors:

- *Comprehensive approach:* implement the package of public derisking measures;
- *Focused approach:* implement certain priority derisking measures only.

Such actions can be guided by an implementation road map and in coordination among ministries, and with international partners and donors.

Technical areas of study that could be further developed:

- For on-grid solar PV (rooftop PV)
  - Technical and financial analysis of the introduction of for instance a net-metering or FiT system for rooftop PV
  - Market assessment of the residential sector for rooftop PV
  - Technical analysis on the use of battery systems in rooftop PV (C&I and residential)

- For off-grid solar PV (solar-battery MG)
  - Geo-spatial modelling of different technology options to understand the lowest cost technology (solar-battery MG, SHS or grid-extension) in any given location
  - Electricity demand assessment to better understand rural electricity demand and current use of electronic appliances
  - Analysis of alternative system sizes for SHS and solar-battery MG to optimally serve electricity demand

- Cross-sectoral
  - Comprehensive solar irradiation analysis to better understand solar capacity in different locations in Cambodia
  - Analysis of externality costs of the baseline energy mix, including social, ecological and human health costs, to better understand the real costs of coal- and hydro based power generation to Cambodia's society and economy
  - Clarification of applicable and tax laws for solar PV imports, and potential adjustment of the conducted cost-benefit-analysis across sub-sectors

Annexes

Annexes

Annex A: Methodology and Data

This Annex sets out the methodology, assumptions and data that have been used in performing the modelling described in this report.

The modelling closely follows the methodology set out in the UNDP 'Derisking Renewable Energy Investment Report' (2013) ("DREI report (2013)"). This Annex is organized in line with the four stages of the DREI report's framework: the Risk Environment Stage (Stage 1); the Public Instrument Stage (Stage 2); the Levelized Cost Stage (Stage 3); and the Evaluation Stage (Stage 4).

All four solar PV sub-sectors analyzed in this report are addressed under each stage.

In addition, the modelling uses the financial tool (in Microsoft Excel) created for the DREI report framework. The financial tool is denominated in 2017 USDs and covers a core period from January 1, 2019 to December 31, 2030 for solar PV on-grid technologies, and January 1, 2019 to December 31, 2025 for solar PV off-grid technologies. Generation technologies have asset lifetimes that extend beyond 2030, which is captured by the financial tool.

The DREI report and the financial tool are available for download at www.undp.org/DREI.

A.1 Risk Environment (Stage 1)

The data for the Risk Environment Stage come from two principal sources:

1. 22 structured interviews held with domestic and international investors and project developers who are considering or are actively involved in on- and off-grid solar PV opportunities in Cambodia and the Southeast Asian region;

2. multiple informational interviews with relevant stakeholders and experts, such as industry practitioners, government officials and international development agency actors active in the on- and of off-grid solar PV space in Cambodia.

In order to gather this data, the UNDP project team conducted three separate missions to Phnom Penh in September and November 2017, and July 2018. Three structured interviews were held remotely over the phone during the same time period.

Deriving a Multi-Stakeholder Barrier and Risk Table

The multi-stakeholder barrier and risk tables for solar PV are derived from the generic table for RE introduced in the DREI report (2013; Section 2.1.1). The generic table is composed of 9 risk categories and 21 underlying barriers. The report has adapted the generic multi-stakeholder barrier and risk tables for all four solar PV sub-sectors to the specific context in Cambodia, including the applicable risk categories and barriers. The adapted tables for each solar PV sub-sector can be found at the end of the individual sub-sector chapters above.

Calculating the Impact of Risk Categories on Higher Financing Costs

The basis of the financing cost waterfalls produced by the modelling is derived from structured, quantitative interviews undertaken with solar PV investors and developers. The interviews were performed on a confidential basis and all data across interviews were aggregated together. The interviews and processing of data followed the methodology described in Box 1 below, with investors scoring each risk category according to: (i) the probability of occurrence of negative events; (ii) the level of financial impact of these events (should they occur); as well as also scoring (iii) the effectiveness of public instruments to address each risk category. Investors were also asked to provide estimates of their cost of equity, cost of debt, capital structure and loan tenors. Interviewees were provided beforehand with an information document setting out key definitions and questions, and the typical interview took between 45 and 90 minutes.

Box 1: Methodology for quantifying the impact of risk categories on higher financing costs

1. Interviews

Interviews were held with debt and equity investors active in solar PV in Cambodia. The interviewees were asked to provide two types of data:

- scores for the various risk categories identified in the barrier and risk framework. The two interview questions used to quantify the risk categories are set out in *Figure 26*;
- the current cost of financing for making an investment today, which represents the end-point of the waterfall (or the starting point in the case of the best-in-class country).

Figure 26: Interview questions to quantify the impact of risk categories on the cost of equity and debt

Q1: How would you rate the probability that the events underlying the particular risk category occur?

UNLIKELY **1** ○ **2** ○ **3** ○ **4** ○ **5** ○ VERY LIKELY

Q2: How would you rate the financial impact of the events underlying the particular risk category, should the events occur?

LOW IMPACT **1** ○ **2** ○ **3** ○ **4** ○ **5** ○ HIGH IMPACT

2. Processing the data gathered

The data gathered from interviews are then processed. The methodology involves identifying the total difference in the cost of equity or debt between the high financing environment (Cambodia) and the best-in-class developed country (Germany for utility-scale PV; synthetic for the other three solar PV sub-sectors). This figure for the total difference reflects the total additional financing cost in the developing country.

The interview scores provided for each risk category address both components of risk: the probability of a negative event occurring above the probability of such an event occurring in a best-in-class country and the financial impact of the event if such an event occurs (see DREI Report (2013; Section 2.1.1). These two ratings are then multiplied to obtain a total score per risk category. These total risk scores are then used to prorate and apportion the total difference in the cost of equity or debt.

A very simplified example, demonstrating the basic approach, is demonstrated in *Figure 27*.

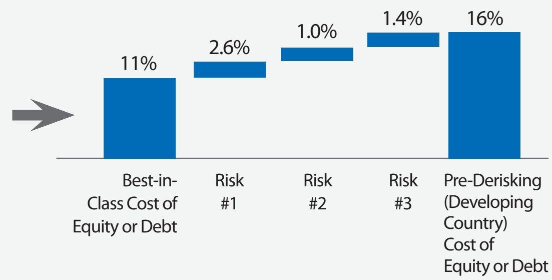
Source: UNDP estimates based on publicly available information.

Figure 27: Illustrative simplified application of the methodology to determine the impact of risk categories on increasing financing costs

COST OF EQUITY	
Developing Country	16%
Best-in-class Developed Country	11%
Total Difference	**5%**

AVERAGE INVESTOR RISK SCORES FOR COST OF EQUITY	Incremental Score for Probability		Score for Impact		Total Risk Score
Risk Category # 1	4	X	4	=	16
Risk Category # 2	2	X	3	=	6
Risk Category # 3	3	X	3	=	9
Total Across all Risks					**31**

PRO-RATING RISK SCORES ACROSS COST OF EQUITY	Pro-rated Risk Score		Total Difference for Cost of Equity		Risk Category Cost of Equity
Risk Category # 1	16/31	X	5%	=	2.6%
Risk Category # 2	6/31	X	5%	=	1.0%
Risk Category # 3	9/31	X	5%	=	1.4%
Total					**5.0%**



In addition, the below key steps have been taken in calculating the financing cost waterfalls:

- In order to make interviews comparable, investors were asked to provide their scores while considering a list of key assumptions regarding the investment into the specific on- and off-grid solar PV technology. *Boxes 2, 3, 4* and *5* set out the key assumptions for each of the analyzed solar PV technology. To maintain consistency, these assumptions were subsequently used to shape the inputs in the LCOE calculations in Stage 3.

Box 2: Investment assumptions for utility-scale PV in Cambodia: Investment assumptions for utility-scale PV in Cambodia

1. Please answer all questions based on the *current* status of the risks in the country's investment environment today
2. Assume you have the opportunity to invest in a 30-100 MW PV solar farm, pre-construction, with a government backed feed-in tariff
3. Assume PV technology from quality manufacturer with proven track record
4. Assume hardware is protected with lifetime performance warrantees
5. Assume that transmission lines with free capacities are located relatively close to the project site (within 10km)
6. Assume payments are made in local currency (KHR)
7. Assume a build-own-operate business model and an EPC sub-contract with high penalties for contract breach
8. Assume a finance structuring with SPV non-recourse project financing

Box 3: Investment assumptions for rooftop PV in Cambodia

1. Please answer all questions based on the *current* status of the risks in the country's investment environment today
2. Assume you have the (pre-construction) opportunity to invest in a portfolio of 0.1-5 MW solar rooftops where the PV is built on the roof of the off-taker that buys 80% of all electricity produced and where 20% of electricity produced will be fed into the grid, at a government backed Feed-in Tariff (FiT)
3. Assume payments are made in local currency (KHR)
4. Assume PV technology from quality manufacturer with proven track record
5. Assume hardware is protected with lifetime performance warrantees
6. Assume a build-own-operate business model and an EPC sub-contract with high penalties for contract breach
7. Assume that you will be investing in a portfolio of projects (or in a company holding such a portfolio)

Box 4: Investment assumptions for solar-battery MG in Cambodia

1. Please answer all questions based on the *current* status of the risks in the country's investment environment today
2. Assume you have the opportunity to invest in multiple solar battery mini-grids, each serving 100 households, in an off-grid concession area in Cambodia
3. Assume proven PV and battery technology from quality manufacturer with proven track record
4. Assume that the electricity tariff reflects the cost of generation and distribution
5. Assume that electronic metering is used, billing occurs in Riels, and that electricity payments are made on a monthly basis through mobile money
6. Assume a build-own-operate business model
7. Assume that the mini-grid will be able to be available 95% of the time

Box 5: Investment assumptions for SHS in Cambodia

1. Please answer all questions based on the *current* status of the risks in the country's investment environment today
2. Assume you have the opportunity to invest in a portfolio of leases for 10,000 PAYGO solar home systems in Cambodia (post construction) to rural consumers
3. Assume PV technology and proven battery technology from quality manufacturer with proven track record
4. Assume a supplier backed maintenance contract
5. Assume that SHS payments are made on a monthly basis through mobile money and in KHR
6. Assume that end-users have reasonable credit ratings
7. Assume that you will be investing in a portfolio of projects (or in a company holding such a portfolio

Exclusion of Risk Categories

Equity investors in solar PV typically have greater exposure to development risks.

- For all four solar PV technologies, the modelling uses the full set of risk categories for equity investors.
- For utility-scale PV, the 'permits risk' category is removed for debt investors, assuming that banks will have prerequisites, such as having licenses, technical feasibility studies, and equity financing in place, before considering a funding request.
- For the three remaining solar PV technologies, risk categories have been assumed the same for equity and debt investors.

Best-in-class investment environment

- For utility-scale PV, the modelling selects Germany as the example of a best-in-class investment environment. Germany is generally considered by international investors to have a very well-designed and implemented policy and regulatory regime, with minimal risk for all 11 investment risk categories. In this way, Germany serves as the baseline – the left-most column of the financing cost waterfall for utility-scale PV.

- For rooftop PV, solar-battery MG and SHS, the authors have applied a 'synthetic' best-in-class approach, where synthetic (or imaginary) best-in-class countries were created with data based on interviews and the authors' knowledge and expertise. This synthetic approach was chosen because it is not entirely clear what the actual best-in-class country is at this moment, and especially solar-battery MG and SHS (in its envisioned business model) are considered early-stage, which makes a comparison with other countries difficult.

Public Cost of Capital

The modelling takes a bottom-up approach to the calculation of the public cost of capital. In this case, the public cost of capital is denominated in USD. The bottom-up approach can then be summarized as follows:

Public Cost of Capital (USD) = Risk-free Rate (USD) + Country Risk Premium

The risk-free rate is taken as the 10-year US Treasury bond rate and the country risk premium is estimated based on either the country's sovereign credit rating or the credit default swap (CDS) spread over the US, depending on the availability of information. Both input parameters are based on publicly available information, with the US 10-year Treasury bond data available from the US Department of Treasury, and the country risk premium data available from academic sources.

For this analysis, as of November 2017, the 10-year US Treasury Bond rate is estimated at 2% and the country risk premium was estimated at 6.4% (rating-based default spread), resulting in an 8% (rounded) public cost of capital for Cambodia.

As the DREI analysis is carried out through its various stages, this bottom-up approach to calculating the public cost of capital is also a reference for the assumed cost of equity and debt assumptions, and is cross-checked in the interviews with industry participants in-country.

A.2 Stage 2 – Public Instruments

Public Instrument Table

The public instrument tables for all four solar PV sub-sectors are derived from the generic table in the DREI report (2013, Section 2.2.1). These tables are set out in full in Annex B.

Policy Derisking Instruments

The below is a summary of the key approaches taken.

- **Public Cost.** Estimates for the public cost of policy derisking instruments are calculated based on bottom-up modelling. This follows the approach for costing set out in the DREI report (2013, Section 2.2.2.). Each instrument has been modelled in terms of the costs of: (i) full-time employees (FTE) at mean yearly costs of USD 6,900 per FTE (based on official income levels of civil servants in Cambodia); and (ii) external consultancies/services estimated at USD 200,000, USD 100,000 and USD 50,000 per large, medium, and small contract, respectively. An annual inflation of 3.5% is assumed for both FTE and consultancies/service contract costs. Typically, full-time employees are modelled for the operation of an instrument (e.g. the full-time employees required to staff an energy regulator) and external consultancies/services are modelled for activities such as the design and evaluation of the instrument, as well as certain services such as publicity/awareness campaigns. For on-grid solar PV, policy derisking measures are modelled for a 12-year period from 2019 to 2030; while for for off-grid solar PV, policy derisking measures are modelled for a 7-year period from 2019 to 2025. Data have been obtained from local experts and the UNDP's in-house experience. See *Table 12* (utility-scale PV), *Table 19* (rooftop PV), *Table 27* (solar-battery MG) and *Table 34* (SHS) for the cost estimates of policy derisking instruments for the four analyzed solar PV sub-sectors. More detailed information on the cost calculation of policy derisking instruments are available upon request.

- **Pro Rating Factor.** Some policy derisking instruments have a cross-sectoral impact and affect more than one solar PV sub-sector. For example, "streamlined, consistent and facilitated customs procedures" will benefit all four solar PV sub-sectors. In such a case, a pro rating factor has been applied which distributes instrument costs among individual solar PV sub-sectors corresponding to their share of the total targeted installed capacity for solar PV.

- **Effectiveness.** Estimates for the effectiveness of policy derisking instruments in reducing financing costs are based on the structured interviews with investors and then further adjusted to reflect UNDP's in-house experience. The assumptions for the final effectiveness of policy derisking instruments for each solar PV sub-sector are illustrated in *Tables 37* to *40* on the following pages. As certain policy derisking instruments may take time to become maximally effective, a linear ("straight-line") approach to time effects is modelled over the target period – this is referred to as the discount for time effects in the table. The qualitative investor feedback on policy derisking instruments' effectiveness is provided in *Table 8* (utility-scale PV), *Table 15* (rooftop PV), *Table 22* (solar-battery MG) and *Table 30* (SHS) of the report.

Table 37: Modelling assumptions for policy derisking instruments' effectiveness – Utility-scale PV

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT (2019-2030)	SOURCE/ COMMENT
Power Market Risk	• Establish long term on-grid PV targets • Strengthen capacities independent market regulator • Implement auction model • Develop standardized and well-designed PPA document and process	75%	50%	Source: Authors and Interview responses
Permits Risk	• Streamline processes for permits and recourse mechanisms • Land administration improvements	75%	50%	
Hardware Risk	• Streamlined, consistent and facilitated customs procedures • Considered approach to customs tariffs • Develop certification and technology standards Enforce standards	50%	50%	
Labor Risk	• Programs to develop competitive • Skilled labor market for solar farms (all roles)	50%	50%	
Developer Risk	(Government) support to grow early-stage industry	25%	50%	
Grid/Transmission Risk	• Develop a grid code for new RE technologies/solar PV • Establish timing targets for connection of new renewable sources to the grid • Policy support for national grid infrastructure planning and development	50%	50%	
Off-taker Credit Risk	• Establish international best practice in off-taker's management and operations and corporate governance • Implement sustainable cost recovery policies	50%	50%	
Financing Risk	Liberalize/improve capacities within domestic financial sector; optimise reserve requirements for domestic lending to businesses; strengthen domestic investors' familiarity with and capacity regarding utility-scale PV	50%	50%	

Table 38: Modelling assumptions for policy derisking instruments' effectiveness – Rooftop PV

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT (2019-2030)	SOURCE/ COMMENT
Power Market Risk	• Establish long term rooftop PV targets • Strengthen capacities independent market regulator • Implement FIT and/or net-metering	75%	50%	Source: Authors and Interview responses
Permits Risk	• Streamlined process for permits, one-stop-shop and recourse mechanisms • Clear zoning approach	50%	50%	
Hardware Risk	• Streamlined, consistent and facilitated customs procedures; • Develop certification, technology standards and enforce standards	50%	50%	
Digital Risk	Well-designed telecom regulations enabling universal, competitive coverage and mobile money	50%	50%	
Labor Risk	Programs to develop competitive, skilled labor market for rooftop PV (all roles)	50%	75%	
Developer Risk	(Government) support to grow early-stage industry	25%	50%	
Grid/Transmission Risk	• Develop a grid code for new RE technologies/solar PV • Policy support for national grid infrastructure planning and development	50%	25%	
End-user Credit Risk	Facilitate growth of C&I credit data industry	50%	75%	
Off-taker Credit Risk	• Establish international best practice in off-taker's management and operations • Implement sustainable cost recovery policies	25%	50%	
Financing Risk	• Strengthen capacities within domestic financial sector • Optimize reserve requirements for domestic lending to busi-nesses Strengthen domestic investors' familiarity with and capacity regarding rooftop PV • Regulatory and tax improvements for asset backed securities	50%	75%	

Table 39: Modelling assumptions for policy derisking instruments' effectiveness – Solar-battery MG

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT (2019-2025)	SOURCE/ COMMENT
Power Market Risk	• Develop realistic and transparent off-grid solar PV targets • Strengthening capacities institutional off-grid electrification management, determine national off-grid electricity service areas for solar-battery MG and define well-designed concessions for developers • Establish regulatory approach with two, co-existing regimes for market access, tariff setting, and technical standards: ◦ Light-Touch: simple mechanism for developers to self-register; no tariff controls; voluntary compliance with comprehensive regime standards; ◦ Comprehensive: well-designed concessions;balanced, regulated tariffs through tariff tables or price discovery.	• Light-touch: 25% • Comprehensive: 50%	50%	Source: Authors and Interview responses
Social Acceptance Risk	Develop and coordinate ongoing community impact and public awareness campaigns on solar-battery MG	50%	50%	
Hardware Risk	• Streamlined, consistent and facilitated customs procedures • Certification/technology standards for solar PV and energy efficient appliances	50%	50%	
Digital Risk	Well-designed telecom regulations enabling universal, competitive coverage and mobile money	50%	50%	
Labor Risk	Programs to develop competitive, skilled labor market for solar-battery MG (all roles)	50%	75%	
Developer Risk	(Government) support to grow early-stage industry	50%	50%	
End-user Credit Risk	Facilitate growth of consumer credit industry; Promote productive use of electricity (mini-grid areas)	25%	75%	
Financing Risk	• Improve capacities within domestic financial sector • Optimise reserve/collateral requirements for domestic lending to green businesses • Regulatory and tax improvements for asset backed securities for MGs; strengthen domestic investors' familiarity with and capacity regarding solar-battery MG and aggregative financing model)	50%	75%	

Table 40: Modelling assumptions for policy derisking instruments' effectiveness – SHS

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT (2019-2025)	SOURCE/ COMMENT
Power Market Risk	• National off-grid targets, tiered approach to statistics • Build capacity of rural energy dept./agency/regulator • Support a "light-touch", phased approach to regulation of SHS companies, with initial minimal self-registration	50%	50%	Source: Authors and Interview responses
Social Acceptance Risk	• Develop and coordinate ongoing community impact and public awareness campaigns on SHS • Technical standards enforcement, outreach to community/ community leaders	50%	50%	
Hardware Risk	• Develop certification and technology standards • Streamlined, consistent and facilitated customs procedures	75%	50%	
Digital Risk	Well-designed telecom regulations enabling universal, competitive coverage and mobile money	50%	50%	
Labor Risk	Programs to develop competitive, skilled labor market for SHS (all roles)	50%	75%	
Developer Risk	(Government) support to grow early-stage industry	50%	50%	
End-user Credit Risk	Facilitate growth of consumer credit industry	25%	75%	
Financing Risk	• Strengthen capacities within domestic financial sector • Optimise reserve requirements for domestic lending to green businesses; Regulatory and tax improvements for asset backed securities • Strengthen domestic investors' familiarity with and capacity regarding SHS and aggregative financing model	50%	75%	

Financial Derisking Instruments

The modelling assumptions for financial derisking instruments are informed by UNDP's in-house experience, including interviews with representatives from international financial institutions and interviews with project developers.

Empirically, the selection, pricing and costing of financial derisking instruments for a particular solar PV investment are determined on a case-by-case basis and reflect the particular risk-return characteristics of that investment. The modelling assumptions instead cover the aggregate investments for Cambodia's envisioned solar PV targets and represent a simplified, but plausible, formulation for the selection and pricing of financial derisking instruments. The following is a summary of the key assumptions for each solar PV sub-sector used.

- Cost estimates of public cost of financial derisking instruments for each solar PV sub-sector are set out in *Tables 41-44* on the following pages.

Table 41: Modelling assumptions on costing of financial derisking instruments – Utility-scale PV

RISK CATEGORY	FINANCIAL DERISKING INSTRUMENT	POLICY DERISKING INSTRUMENT
Grid/Transmission Risk	Take-or-Pay Clause in PPA	• Assumes 1% of annual production is lost due to grid management (curtailment) or transmission failures (black-out/brown-out) • Assumes 100% of IPP's lost revenues due to grid management or transmission failures are reimbursed by take-or-pay clause
Off-taker Credit Risk	Government (sovereign) Guarantee	• Assumes the Government of Cambodia provides "Letter of Support" for each PPA entered into between EDC and the IPP • The public cost of this type of guarantee are modelled as opportunity cost to the Government of Cambodia from setting aside 12 months' worth of PPA payments at 6% cost of capital (public cost of capital of 8% minus 10y US Treasury bond rate of 2%)
Financing Risk	Public Loan	• Assumes concessional (6% and 10-year tenor) USD loans from multilateral development banks to cover: ◦ 25% of the total debt post-derisking • Public cost: ◦ assumes the public cost is 25% (loss reserve) of the face value of the loan to the IPP (World Bank, 2011)

Source: Authors, unless otherwise stated.

Table 42: Modelling assumptions on costing of financial derisking instruments – Rooftop PV

RISK CATEGORY	FINANCIAL DERISKING INSTRUMENT	POLICY DERISKING INSTRUMENT
Developer Risk End-user Credit Risk Financing Risk	Credit lines/public loans to rooftop PV developers/investors	• Assumes concessional (8% and 10-year tenor) USD loans from multilateral development banks to cover: ◦ 25% of the total debt post-derisking • Public cost: ◦ assumes the public cost is 25% (loss reserve) of the face value of the loan (World Bank, 2011)
Developer Risk End-user Credit Risk Financing Risk	Partial Loan Guarantees	• Assumes a partial loan guarantee at 80% of the face value of the commercial loan. Assumes no matching sovereign guarantee is required by domestic government • Assumes an interest rate of 8.4% and a loan tenor of 10 years • Private sector cost (fee structure) assumes 200 basis points (2%) loan guarantee fee, calculated annually, based on the average outstanding value of the commercial loan covered by the guarantee • Public Cost: ◦ assumes the public cost is 25% (loss reserve) of the face value of the guarantee (World Bank, 2011); ◦ assumes no paid-in-capital multiplier.

Source: Authors, unless otherwise stated.

Table 43: Modelling assumptions on costing of financial derisking instruments – Solar-battery MG

RISK CATEGORY	FINANCIAL DERISKING INSTRUMENT	POLICY DERISKING INSTRUMENT
Power Market Risk	Grid Expansion Compensation	• Only applicable to mini-grid investments operating under the comprehensive regulatory track • Assumes cost as opportunity costs • The model assumes that the compensation is the difference between the LCOE of the solar-battery MG and the national retail tariff. Post-derisking solar-battery MG tariff: 0.78 USD/kWh, National retail tariff: 0.15 USD/kWh difference to be covered by instrument: 0.61 USD/kWh) • Assumes an illustrative 20% mini-grids are exposed to grid extension in their 10th year of operation (mid-point of their investment lifetimes) • Replacement is assumed to occur linear, i.e. 2% of all solar-battery MG will be replaced by the national grid each year • Lifetime of MG investment is assumed at 20 years • Compensation is paid for remaining expected energy output from the time the grid arrives until the assumed payback period has been reached. • Public cost: ◦ assumes the public cost is 100% (loss reserve) of the compensation
Developer Risk End-user Credit Risk Financing Risk	Credit lines/public loans to solar-battery MG developers	• Assumes an interest rate of 8% and a loan tenor of 10 years • Assumes a front-end fee of 100 basis points (1%) • Public cost: ◦ assumes the public cost is 25% (loss reserve) of the face value of the loan (World Bank, 2011)

Developer Risk
End-user Credit Risk
Financing Risk
	Partial Loan Guarantees	• Assumes a partial loan guarantee at 80% of the face value of the commercial loan, to avoid moral hazard. Assumes no matching sovereign guarantee is required by domestic government
		• Assumes an interest rate of 9.7% and a loan tenor of 10 years
		• Assumes a front-end fee of 100 basis points (1%)
		• Private sector cost (fee structure) assumes 200 basis points (2%) loan guarantee fee
		• Public Cost:
		  ◦ assumes the public cost is 25% (loss reserve) of the face value of the guarantee (World Bank, 2011);
		  ◦ assumes no paid-in-capital multiplier.

Source: Authors, unless otherwise stated.

Table 44: Modelling assumptions on costing of financial derisking instruments – SHS

RISK CATEGORY	FINANCIAL DERISKING INSTRUMENT	POLICY DERISKING INSTRUMENT

Developer Risk
End-user Credit Risk
Financing Risk
	Credit lines/ public loans to SHS developers/investors	• Assumes concessional (8% and 10-year tenor) USD loans from multilateral development banks to cover:
		  ◦ 25% of the total debt post-derisking
		• Public cost:
		  ◦ assumes the public cost is 25% (loss reserve) of the face value of the loan (World Bank, 2011)

Developer Risk
End-user Credit Risk
Financing Risk
	Partial Loan Guarantees	• Assumes a partial loan guarantee at 80% of the face value of the commercial loan. Assumes no matching sovereign guarantee is required by domestic government
		• Assumes an interest rate of 9.7% and a loan tenor of 10 years
		• Public Cost:
		  ◦ assumes the public cost is 25% (loss reserve) of the face value of the guarantee (World Bank, 2011);
		  ◦ assumes no paid-in-capital multiplier.

Source: Authors, unless otherwise stated.

- Effectiveness estimates for the financial derisking instruments in reducing financing costs are based on the structured interviews with investors, and then further adjusted to reflect UNDP's in-house experience. The figures for effectiveness have full and immediate impact once the instrument is implemented (i.e. no timing discount). The assumptions for effectiveness of financial derisking instruments for each solar PV sub-sector are illustrated in *Tables 45 to 48* below. The qualitative investor feedback on derisking instruments' effectiveness is provided in *Table 8* (utility-scale PV), *Table 15* (rooftop PV), *Table 22* (solar-battery MG) and Table 30 (SHS) of the report.

Table 45: Modelling assumptions for financial derisking instruments' effectiveness – Utility-scale PV

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS[149]	DISCOUNT FOR TIME EFFECT	SOURCE/ COMMENT
Grid/Transmission Risk	Take-or-Pay Clause in PPA	50%	0%	Source: Authors and Interview responses
Off-taker Credit Risk	Government (sovereign) Guarantee	50%	0%	
Off-taker Credit Risk	Credit lines to domestic, commercial banks	0%	0%	
Financing Risk	Public Loan	0%	0%	

Table 46: Modelling assumptions for financial derisking instruments' effectiveness – Rooftop PV

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT	SOURCE/ COMMENT
Developer Risk End-user Credit Risk Financing Risk	Credit lines to domestic, commercial banks	25%	0%	Source: Authors and Interview responses
	Partial Loan Guarantees	25%	0%	

Table 47: Modelling assumptions for financial derisking instruments' effectiveness – Solar-battery MG

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT	SOURCE/ COMMENT
Power Market Risk	Grid Expansion Compensation	25%	0%	Source: Authors and Interview responses
Developer Risk End-user Credit Risk Financing Risk	Credit lines to domestic, commercial banks	25%	0%	
	Partial Loan Guarantees	25%	0%	

Table 48: Modelling assumptions for financial derisking instruments' effectiveness – SHS

RISK CATEGORY	POLICY DERISKING INSTRUMENT	EFFECTIVENESS	DISCOUNT FOR TIME EFFECT	SOURCE/ COMMENT
Developer Risk End-user Credit Risk Financing Risk	Credit lines to domestic, commercial banks	25%	0%	Source: Authors and Interview responses
	Partial Loan Guarantees	25%	0%	

[149] For some risk categories multiple policy and financial derisking instruments apply. Due to the underlying modelling methodology, the combined effectiveness percentage of policy and financial derisking instruments cannot exceed 100%. Therefore, in some cases, the effectiveness was capped to not exceed 100%.

A.3 Stage 3 – Levelized Costs

Levelized Cost of Electricity (LCOE) Calculation

The DREI report's (2013) financial tool is used for the LCOE calculations. The financial tool is based on the equity-share based approach to LCOEs, which is also used by ECN and the National Renewable Energy Laboratory (NREL) (IEA, 2011; NREL, 2011). Box 6 sets out the LCOE formula used. In this approach, a capital structure (debt and equity) is determined for the investment, and the cost of equity is used to discount the energy cash-flows.

Box 6: The modelling LCOE formula

$$\frac{\%\,\text{Equity Capital} * \text{Total Investment} + \sum_{\tau=1}^{T} \frac{(\textit{O\&M Expense})_\tau + (\textit{Debt Financing Costs})_\tau - \textit{Tax Rate} * (\textit{Interest Expense}_\tau + \text{Depreciation}_\tau + \textit{O\&M Expense}_\tau)}{(1 + \textit{Cost of}\ \text{Equity})^\tau}}{\sum_{\tau=1}^{T} \frac{\textit{Electricity Production}_\tau * (1 - \textit{Tax Rate})}{(1 + \textit{Cost of}\ \text{Equity})^\tau}}$$

Where,

% Equity Capital = portion of the investment funded by equity investors

O&M Expense = operations and maintenance expenses

Debt Financing Costs = interest & principal payments on debt

Depreciation = depreciation on fixed assets

Cost of Equity = after-tax target equity IRR

Baseline Energy Mix Levelized Costs and Emissions

The modelling makes a number of important methodological choices and assumptions regarding the baseline energy mix for on-grid and off-grid solar PV. The key steps in the approach taken are set out below.

- **On-grid Solar PV**
  - **Baseline approach**
    - On-grid solar PV investments are made in the context of an existing or evolving (with new installed capacity coming online) electricity generation mix. The model assumes that Cambodia, in its BAU scenario will continue to add super-critical coal and large hydro power plants as main means to increase its electricity generation capacity in the future[150]. The baseline technology mix therefore assumes a marginal baseline approach of 50% coal (supercritical) and 50% large hydro. The modelling assumptions for coal and large hydro are illustrated in *Table 49* and *Table 50*, respectively.
    - The baseline reflects generation, and does not include transmission and distribution costs, nor transmission losses. Further, the baseline generation calculation is sensitive to technology choice assumptions, and does not reflect externalities including carbon pricing, water pollution, fishing stock depletion, toxic coal waste, air pollution, and the long-term damage to ecosystems and human health.

[150] This assumption is based on the publicly available generation expansion plan (MIME and IRENA, 2016).

- Assumptions do not reflect location-specific parameters
- Although Cambodia is assumed to have considerable natural gas resources in the Gulf of Thailand, no concrete plans to introduce gas into the national electricity mix exist as of today, and therefore, gas has not been considered in the future baseline mix.
- Cambodia currently does not subsidise coal. The modelling exercise therefore uses unsubsidised fuel prices for coal.
- Coal prices are projected using the World Bank Commodities Price Forecast (Australia, constant USD).
- The modelling assumes a combined baseline grid emission factor equating to 0.458 tonnes of CO_2e/MWh.

Table 49: Modelling assumptions for the marginal baseline energy technology (Coal-Fired Thermal Plants)

TECHNOLOGY ITEM	ASSUMPTION	SOURCE/COMMENTS
Investment costs (USD/MW)	1,600,000	IEA (2015); Economic analysis of a supercritical coal-fired power plant in Cambodia (2013)
Lifetime of investment	35 years	Steven J Davis and Robert H Socolow (2014); Schmidt et al (2012); Journal of Industrial Engineering International (2015)
Plant efficiency	45%	UNFCCC CDM, Supercritical coal fire plant (construction after year 2000)
Capacity factor	60%	EAC (2017)
Emission factor (tCO_2/MWh)	0.915	CDM project Cambodia (2012); Stornoway (2015)
O&M Cost (USD/MW)	53,000	IEA (2015); year 2024 - mid-point of modelled investment period
O&M Inflation	3.5%	Authors
Fuel Cost (USD/MWh)	2052: 3.59 2019: 10.81	World Bank Commodities Price Forecast (April 2018)
Fuel Subsidies	0	Authors
Depreciation allocation	Straight line, 100% depreciable	VDB Loi (2016)
FINANCING ITEM	**ASSUMPTION**	**SOURCE/COMMENTS**
Capital Structure	Debt/Equity: 70/30%	Economic analysis of a supercritical coal-fired power plant in Cambodia (2013)
Cost of Debt	7.7%	Author; same as for RE, 15% discounted to account for market maturity for fossil thermal plants and historical track record of these types of investments
Loan Tenor	17.5 years	Author; half the lifespan of asset
Cost of Equity	12.8%	Author; same as for RE, 15% discounted to account for market maturity for fossil thermal plants and historical track record of these types of investments

Table 50: Modelling assumptions for the marginal baseline energy technology (Large Hydro; >200 MW)

TECHNOLOGY ITEM	ASSUMPTION	SOURCE/COMMENTS
Investment costs (USD/MW)	2,500,000	IEA (2015)
Lifetime of investment (years)	35 years	IEA (2015)
Plant efficiency	93%	UNFCCC CDM hydro projects Cambodia (2012); John Zactruba (2010)
Capacity factor	36%	EAC (2018)
Emission factor (tCO_2/MWh)	0	UNFCCC CDM Methodology ACM0002
O&M Cost (USD/MW/a)	35,000	UNFCCC CDM hydro projects Cambodia (2012)
O&M Inflation	3.5%	Authors
Fuel Cost (USD/MWh)	0	Authors
Fuel Subsidies	0	Authors
Depreciation allocation	Straight line, 100% depreciable	VDB Loi (2016)
FINANCING ITEM	**ASSUMPTION**	**SOURCE/COMMENTS**
Capital Structure	Debt/Equity: 70/30%	Authors
Cost of Debt	7.7%	Author; same as for RE, 15% discounted to account for market maturity for fossil thermal plants and historical track record of these types of investments
Loan Tenor	17.5 years	Author; half the lifespan of asset
Cost of Equity	12.8%	Author; same as for RE, 15% discounted to account for market maturity for fossil thermal plants and historical track record of these types of investments

- **Off-grid Solar PV**
  - **Baseline approach**
    - **Solar-battery MG**
      - The baseline assumes the use of a demand-reflective diesel-based MG. The demand for a diesel-based and solar-battery MG has been modelled considering typical electrical appliances, power consumption rates and usage duration in rural areas in Cambodia. The electricity demand modelling estimates future electricity needs of three end-user types, namely individual households, productive use and community/social infrastructure. This electrification scenario also reflects the shift from the provision of basic electrification to households for lighting and mobile phone charging, towards a relatively more advanced level, which includes additional appliances for households (e.g. TVs, fans), productive use (e.g. agricultural mills, water pumps, restaurants), and social/community services (street lighting). *Table 51* illustrates the applied electricity demand assumptions for an average rural village in Cambodia.

- The model assumes a generic village of 100 households. The daily electricity use and the types of appliances used are informed by literature and by interviews with Rural Electricity Enterprises (REEs) in Cambodia, and off-grid solar PV developers.
- Based on the electricity demand profile for the generic village, the power generation capacity of the baseline diesel-based and solar-battery PV MG are calculated. The modelling assumes that 95% of the demand is met by the mini-grids.
- For the diesel-based MG, the diesel generator capacity is determined by peak demand of the generic village, with an additional safety margin of 20%.
- For solar-battery MG, the size of the MG is calculated based on a dispatch algorithm whereby the electricity generated by the solar panels are used at the time of generation, with the excess stored to and discharged from the battery at night (or on cloudy days). Using Microsoft Excel's solver function, the solar PV and battery sizes are optimized for the lowest LCOE, provided that the service level does not fall below 95%.
- The diesel-based mini-grid baseline reflects generation, transmission and distribution costs, as well as transmission losses. *Table 52* provides an overview of key modelling assumptions for a diesel-based MG.
- The modelling assumes a mini-grid baseline grid emission factor equating to 0.889 tonnes of CO_2e/MWh.

Table 51: Rural electricity demand assumptions for an average village in Cambodia using Solar-battery MG

Sector	Consumer Type	Electrical Appliance	Power Consumption (W)	Quantity/Consumer Type	Load (W)	Start time	End time	Usage duration per day	Energy Required per Day/Consumer Type
Household	Household	Lamp (inside house)	5	3	15	18.00	22.00	4	60
Household	Household	Lamp (outside house)	5	1	5	19.00	24.00	5	25
Household	Household	Phone Charging	5	2	10	22.00	2.00	4	40
Household	Household	Table Fan	50	1	50	18.00	23.00	5	250
Household	Household	TV	50	0,2	10	19.00	22.00	3	30
Household	Household	Rice Cooker (lunch)	250	0,2	50	10.00	11.00	1	50
Household	Household	Rice Cooker (dinner)	250	0,2	50	17.00	18.00	1	50
Productive Use	Restaurant	Refrigerator	200	2	400	7.00	19.00	12	4.800
Productive Use	Restaurant	Rice Cooker	250	2	500	12.00	16.00	4	2.000
Productive Use	Restaurant	Large TV	100	2	200	7.00	12.00	5	1.000
Productive Use	Restaurant	Lamps	10	5	50	18.00	23.00	5	250
Productive Use	Agricultural Mill	Agricultural Mill	10.000	0	0	11.00	13.00	2	0
Productive Use	Water pump	Water pump	250	2	500	11.00	16.00	5	2.500
Productive Use	Sewing machine	Sewing machine	120	2	240	9.00	13.00	4	960
Social Infrastructure	School	School Lighting	5	10	50	8.00	15.00	7	350
Social Infrastructure	School	School Fan	50	1	50	8.00	15.00	7	350
Social Infrastructure	Street Lights	Street Lamps	5	4	20	18.00	7.00	13	260

Source: Authors, informed by local experts.

Table 52: Modelling assumptions diesel-based MG

GENERAL ASSUMPTIONS	VALUE	DESCRIPTION/COMMENTS/SOURCE
BAU scenario for the LCOE modelling	Diesel Generator	Authors
Effective Tax Rate	20%	VDB Loi (2016)
Public Cost of Capital	8.0%	Authors
INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	**VALUE**	**DESCRIPTION/COMMENTS/SOURCE**
System Size & Safety Factor	System Size: 10.8 kW (including 20% safety Factor)	Diesel system size, i.e. generator capacity, is based on peak demand plus an additional safety factor.
Investment costs, generation and distribution	Generation Cost: 255 USD/kw Distribution Cost: 1.8 km line @ USD 7,200 per km End-user wiring/labor cost: 225 USD/household	Authors; informed by local experts
Lifetime of investment	20 years	Authors
Life of diesel generator	50,000 hours	Solar/Diesel Mini-Grid Handbook, Power and Water Corporation, Australia
Life of distribution assets	20 years	Authors
Diesel Generator – Minimum Load	30%	Authors
Distribution Losses	10%	Authors
Emission factor (tCO_2/MWh)	0.89	UNDP (2013; Standardized Baseline Assessment for Off-Grid Rural Electrification in Sub-Saharan Africa)
O&M Cost for Diesel Generator, excluding fuel (USD/kWh)	0.02	Frauenhofer Institute (2013)
O&M (annual increase)	3.5%	Authors
Fuel Cost, including transportation of diesel	Diesel Price: 0.9 USD/L Subsidy: 0% Transportation Costs: 0.13 USD/L	Authors; informed by local experts
Depreciation allocation	Straight line, 100% depreciable	VDB Loi (2016)
FINANCING ASSUMPTIONS	**VALUE**	**DESCRIPTION/COMMENTS/SOURCE**
Capital Structure	100% Equity	Authors; informed by local experts
Cost of Equity	19%	Authors; assumed same as for solar-battery MG

- **SHS**
  - For SHS, the baseline assumes the use of diesel generators in village charging stations common in Cambodia. Households typically charge their rechargeable car batteries at these stations and use the battery for electricity. The electricity demand modelling for SHS estimates future electricity needs of households only and excludes productive use and community/social infrastructure needs.
  - The diesel generator system at a common village charging station is assumed similar to the diesel-based MG and assumptions in *Table 52* apply (except distribution costs which do not occur for SHS).
  - The modelling assumes a baseline grid emission factor equating to 0.889 tonnes of CO_2e/MWh.
  - Different to diesel-based MG baseline modelling, the electricity demand modelling for SHS estimates future electricity needs for households only and excludes productive use and community/social infrastructure needs. *Table 53* illustrates the assumed electricity demand of a rural household in Cambodia.

Table 53: Electricity demand assumptions for a rural household in Cambodia using SHS

Sector	Consumer Type	Electrical Appliance	Power Consumption (W)	Quantity/Consumer Type	Load (W)	Start time	End time	Usage duration per day	Energy Required per Day/Consumer Type
Household	Household	Lamp (inside house)	5	3	15	18.00	22.00	4	60
Household	Household	Lamp (outside house)	5	1	5	19.00	24.00	5	25
Household	Household	Phone Charging	5	2	10	22.00	2.00	4	40
Household	Household	Table Fan	50	1	50	18.00	23.00	5	250
Household	Household	TV	50	0,2	10	19.00	22.00	3	30
Household	Household	Rice Cooker (lunch)	250	0,2	50	10.00	11.00	1	50
Household	Household	Rice Cooker (dinner)	250	0,2	50	17.00	18.00	1	50

Source: Authors, informed by local experts.

Solar PV – Technology and financial assumptions

Tables 54-57 on the following pages set out the technical and financial modelling assumptions for the LCOE calculations of the four modelled solar PV technologies.

Table 54: Technology and financial modelling assumptions for Utility-scale PV

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE		DESCRIPTION/COMMENTS/SOURCE
Target Installed Capacity (MW)	350 MW by 2030		Authors; based on anticipated 2030 total installed capacity in Cambodia (IRENA, 2016); verified by EAC and local solar PV project developer
Capacity Factor	17.1%; 1,500 full load hours per year		Authors; informed by local experts
Lifetime of assets (years)	25		Authors
Annual degradation	0.7%		Authors; informed by local experts
Investment Cost (USD/MW)	800,000		IRENA (2016); The Fauenhofer Institute (2015); presents the mid-point cost assumption in the year 2024. Costs for 2018 are assumed at 1,400,000 USD/MW, and 700,400 USD/MW in 2030. A slowdown in cost saving opportunities is expected due to only limited future cost reduction potentials from modules. Cost reduction opportunities in the future are expected from BOS.
O&M Cost (USD/MW/y)	20,000		The Fauenhofer Institute (2015); presents the mid-point cost assumption in the year 2024. Costs for 2014 are assumed at 23,000 USD/MW/year, and 18,000 USD/MW/year in 2030.
O&M Inflation	3.5%		Authors
FINANCING ASSUMPTIONS	**ASSUMPTIONS**		**DESCRIPTION/COMMENTS/SOURCE**
	PRE-DERISKING	**POST-DERISKING**	
Cost of Debt – commercial	9%	6.7%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – public loan	NA	6%	Authors
Loan Tenor – commercial	10 years	10 years	Informed by interviews with investors
Loan Tenor – public loan	NA	10 Years	Authors
Cost of Equity	15%	12%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Capital Structure	50% Equity; 50% Debt	25% Equity; 75% Debt	Authors
Share of debt financing	100% commercial debt w/o guarantees	75% Commercial Debt w/o guarantees, 25% Public Loan	Authors
Depreciation	Straight line, 5% with a non-depreciable value of 5% to account for land value		Authors
Grid interconnection cost	Included in investment and O&M cost		IRENA (2016); The Fauenhofer Institute (2015)

Table 55: Technology and financial modelling assumptions for Rooftop PV

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE		DESCRIPTION/COMMENTS/SOURCE
Target Installed Capacity (MW)	350 MW by 2030		Authors; based on anticipated 2030 total installed capacity in Cambodia (IRENA, 2016); verified by EAC and local solar PV project developer
Capacity Factor	17.1%; 1,500 full load hours per year		Authors; informed by local experts
Lifetime of assets (years)	25		Authors
Annual degradation	0.7%		Authors; informed by local experts
Investment Cost – Hardware PV Module	USD 0.61/Watt peak		Authors; informed by local experts
Investment Cost – Hardware Inverter, BOS	USD 0.22/Watt peak		Authors; informed by local experts
Investment Cost – Soft Costs Permitting, Labor	USD 0.04/Watt peak		Authors; informed by local experts
Consumption Tariff for End-User	USD 0.16/kWh		EDC, Electricity Tariff Plan 2015-2020
Sales Tax (Standard)	10%		Ministry of Economy and Finance (2018)
O&M Costs (as % of Investment Costs)	2.5%		Authors; informed by local experts
O&M Inflation	3.5%		Authors
Insurance Costs (as % of Investment Costs)	0.25%		Authors; informed by local experts
Insurance Coverage Period	15 years		Authors; informed by local experts
FINANCING ASSUMPTIONS	**ASSUMPTIONS**		**DESCRIPTION/COMMENTS/SOURCE**
	PRE-DERISKING	**POST-DERISKING**	
Export of Power – End-user model	Captive Use: 100% Export Use: 0%	Captive Use: 80% Export Use: 20%	Authors
Export of Power – Export Tariff	NA	USD 0.16 / kWh	Authors
Cost of debt – commercial w/o guarantees	10%	8.4%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – commercial w/ guarantees	NA	8.4%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – public loan	NA	8%	Authors
Loan Tenor - commercial w/o guarantees	10 years	10 years	Informed by interviews with investors
Loan Tenor – commercial w/ guarantees	NA	10 years	Authors
Loan Tenor – public loan	NA	10 years	Authors
Cost of Equity	17%	14.5%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Capital Structure	75% Equity; 25% Debt	25% Equity; 75% Debt	Authors
Share of debt financing	100% commercial debt w/o guarantees	50% Commercial Debt w/o guarantees, 25% Commercial Debt w/ guarantees, 25% Public Loan	Authors
Depreciation	Straight line, 100% depreciable		Authors

Table 56: Technology and financial modelling assumptions for Solar-battery MG (Part I)

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE	DESCRIPTION/COMMENTS/SOURCE
Target Installed Capacity (MW)	Illustrative 10 MW "Building Block" by 2025	Authors; 10 MW building blocks targets can be multiplied.
SYSTEM INPUTS		
Solar PV		
PV module size	20.4 kWp	Modelling result
Number of modules	1	Modelling result
Battery		
Battery Technology	Lithium-ion	Authors; informed by local experts
Battery Maximum Load	9 kW	Authors; informed by local experts
Battery Safety Factor	20%	Authors; informed by local experts
Battery Power	11 kW	Authors; informed by local experts
Battery Size	65 kWh	Modelling result
INVESTMENT		
Lifetime of investment	20 years	The Fauenhofer Institute (2013); confirmed by local experts
Livetime of Battery	5 years	Authors; informed by local experts
Depreciable base	100%	Authors
Effective tax rate	20%	VDB Loi (2016)
Investment Costs		
Solar PV Modules	500 USD/kWp	Authors; informed by local experts
Battery	420 USD/kWp	Authors; informed by local experts
Inverter	300 USD/kWp	Authors; informed by local experts
BOS	20% of system costs	Authors; informed by local experts
Low Voltage Distribution Line, Distance	1.8 km	Authors; informed by local experts
Low Voltage Distribution Line, Cost	7,200 USD/km	Authors; informed by local experts
End-user Equipment	110 USD/end-user	Authors; informed by local experts
Distribution network lifetime	20 years	Authors; informed by local experts
GENERATION AND DISTRIBUTION		
Distribution Losses	10%	Authors; informed by local experts
Nominal Operating Cell Temperature (NOCT)	70 degree celsius	Authors; informed by local experts
Maximum Power Temperature Coefficient	-0.35%	Authors; informed by local experts; assumes module CS5P-200M Canadian Solar
Tilt Angle	15 degrees	Authors; informed by local experts
Battery roundtrip efficiency	89.5%	Authors; informed by local experts
Battery Efficiency (charge/discharge)	94.6%	Authors; informed by local experts
Battery Calendar lifetime	5 years	Authors; informed by local experts

Table 56: Technology and financial modelling assumptions for Solar-battery MG (Part II)

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE			DESCRIPTION/COMMENTS/SOURCE
Replacement of inverter and battery chargers	7 years			Authors; informed by local experts
O&M Costs (as % of Investment Costs)	3%			Authors; informed by local experts
O&M Inflation	3.5%			Authors
Reduction in battery cost per year	12%			Schmidt et al (2017)
Reduction in inverter cost per year	4%			IRENA (2016)
	ASSUMPTIONS			
FINANCING ASSUMPTIONS	**PRE-DERISKING**	**POST-DERISKING – COMPREHENSIVE REGIME**	**POST-DERISKING – LIGHT-TOUCH REGIME**	**DESCRIPTION/COMMENTS/SOURCE**
Cost of debt – commercial w/o guarantees	11%	9.7%	NA	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – commercial w/ guarantees	NA	9.7%	NA	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – public loan	NA	8%	NA	Authors
Loan Tenor – commercial w/o guarantees	10 years	10 years	NA	Informed by interviews with investors
Loan Tenor – commercial w/ guarantees	NA	10 years	NA	Authors
Loan Tenor – public loan	NA	10 Years	NA	Authors
Cost of Equity	19%	16.6%	17.8%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Capital Structure	100% Equity; 0% Debt	65% Equity; 25% Debt; 10% Grants	90% Equity; 0% Debt; 10% Grants	Authors
Share of debt financing	100% commercial debt w/o guarantees	25% Commercial Debt w/o guarantees, 25% Commercial Debt w/guarantees, 50% Public Loan	NA	Authors
Depreciation	Straight line, 100% depreciable			Authors

Table 57: Technology and financial modelling assumptions for SHS (Part I)

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE	DESCRIPTION/COMMENTS/SOURCE
Target Installed Capacity (MW)	Illustrative 10 MW "Building Block" by 2025	Authors; 10 MW building blocks targets can be multiplied.
SHS Generation Capacity	100 Wp	Authors
Number of household connections	100,000	10 MW target to be achieved with 100W SHS systems = 100,000 households
Lifetime of investment	10 years	Authors
Lease term	3 years	Authors
Diffusion trajectory	linear	Authors
Annual degradation	0.7%	Authors; informed by local SHS developer
Customer down payment	10%	Authors
UNIT-LINKED EXPENSES PRIOR TO SALE OF SHS		
Costs of Goods sold		
Battery Technology	Lithium-ion	Authors; informed by local SHS developer
PV Modules	0,87 USD/Wp	Authors; informed by local SHS developer
Li-Ion Battery	0,9 USD/Wp	Authors; informed by local SHS developer
Inverters, Charge Controllers and other BOS	1.5 USD/Wp	Authors; informed by local SHS developer
Other Hardware related costs (incl. storage, freight, certification, etc.)	0,09 USD/Wp	Authors; informed by local SHS developer
LED Lights	8 USD/SHS Unit	Authors; informed by local SHS developer
TV	108 USD/SHS Unit	Authors; informed by local SHS developer
Radio	4 USD/SHS Unit	Authors; informed by local SHS developer
Fan	13.5 USD/SHS Unit	Authors; informed by local SHS developer
Cell phone charger	1.5 USD/SHS Unit	Authors; informed by local SHS developer
Autonomous torch	3.5 USD/SHS Unit	Authors; informed by local SHS developer
PAYG Software Licence Fee	2% of sales price	Authors; informed by local SHS developer
Learning Effects		
PV Modules	5% cost reduction per year	Authors
Li-ion Battery	12% cost reduction per year	Schmidt et al (2017)
Charge Controller and other	5% cost reduction per year	Authors
All appliances	5% cost reduction per year	Authors
UNIT-LINKED EXPENSES AT THE TIME OF SALE OF SHS		
Installation	4% of sales price	Authors
Sales Agent Commission	2% of sales price	Authors
Marketing Expense	4% of sales price	Authors
Transportation and movement of system	2% of sales price	Authors
UNIT-LINKED EXPENSES OVER THE LEASE PERIOD		
Mobile money charges and SMS fees	3% of periodic payments	Authors
Provision for Payment Defaults	5% of sales price	Authors

Table 57: Technology and financial modelling assumptions for SHS (Part II)

INVESTMENT COST AND OPERATIONAL ASSUMPTIONS	VALUE		DESCRIPTION/COMMENTS/SOURCE
SELLING, GENERAL AND ADMINISTRATIVE (SG&A) EXPENSES			
Number of SHS companies in the sector	5		Authors
Fixes SG&A			Authors
Local Personnel Expense – Operations (HR, Procurement, Finance, etc.)	20.000 USD/year/company		Authors; informed by local SHS developer
Variable SG&A			IRENA (2016)
Local Personnel Expense, Sales	5% of revenue		Authors; informed by local SHS developer
Rental Expense (for showrooms, or stores)	2% of revenue		Authors; informed by local SHS developer
Customer Support Expense (call center expense, phone lines, etc.)	2% of revenue		Authors; informed by local SHS developer
Annual increase in fixed SG&A expenses	3.5%		Authors
FIXED COSTS (DEPRECIABLE ASSETS)			
PAYG Platform Set-Up	5.000 USD/company		Authors; informed by local SHS developer
Life of PAYG Platform	5 years		Authors; informed by local SHS developer
Office Space/Furniture/Equipment	25.000 USD/company		Authors; informed by local SHS developer
Life of Other Fixed Assets	10 years		Authors
FINANCING ASSUMPTIONS	**ASSUMPTIONS**		**DESCRIPTION/COMMENTS/SOURCE**
	PRE-DERISKING	**POST-DERISKING**	
Cost of debt – commercial w/o guarantees	11%	9.7%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – commercial w/guarantees	NA	9.7%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of debt – public loan	NA	8%	Authors
Loan Tenor – commercial w/o guarantees	10 years	10 years	Informed by interviews with investors
Loan Tenor – commercial w/guarantees	NA	10 years	Authors
Loan Tenor – public loan	NA	10 Years	Authors
Cost of Equity – commercial	19%	16.9%	Authors; informed by interviews with investors and adjusted based on a bottom-up calculation considering the US Government 10-year bond rate, a country risk premium and a sector premium/spread
Cost of Equity – grants	NA	0%	Authors
Capital Structure	100% Equity; 0% Debt	50% Equity; 50% Debt	Authors
Share of debt financing	N/A	25% Commercial Debt w/o guarantees, 25% Commercial Debt w/guarantees, 50% Public Loan	Authors
Share of equity financing	100% commercial equity	87% Commercial Equity, 13% Grant Equity	Authors
Depreciation	Straight line, 100% depreciable		Authors

A.4 Stage 4 – Evaluation

Performance Metrics:

The DREI framework provides four quantitative performance metrics to facilitate the assessment of possible instrument portfolios. These performance metrics are not intended to provide definitive answers to an inherently political process but, rather, to help structure discussions among relevant stakeholders.

The four performance metrics are as follows:

I. Investment Leverage Ratio

II. Savings Leverage Ratio

III. End-user Affordability

IV. Carbon Abatement

The following describes the function and rational of each metric in more detail:

i. Investment Leverage Ratio

The investment leverage ratio can be used to compare the effectiveness of different instrument sets in attracting a certain amount of private investment. The framework's first metric thereby aims to capture the effectiveness of a systemic market transformation effort. The metric requires a target for investment to be set, it then compares the total cost of all public instruments deployed to transform a solar PV market versus the resulting private sector investment to meet the target. As both the costs of the public instruments and the solar PV investments occur over time, the present value[151] of the costs and investments are used to calculate the investment leverage ratio.

Assuming the government has to spend 5 units of public money to trigger private sector investment worth 10 units, the investment leverage ratio would be 2. A higher investment leverage ratio means a higher level of efficiency in terms of transforming a market.

ii. Savings Leverage Ratio

The framework's second metric, the savings leverage ratio, takes a social perspective and compares the cost of derisking instruments deployed versus the economic savings that result from deploying the derisking instruments.

The savings leverage ratio isolates the cost of the newly-introduced derisking instruments. The cost of these derisking instruments is then compared with the difference between the pre- and post-derisking incremental costs. As the derisking instruments' costs as well as the savings occur over time, the present value of the costs and savings are used to calculate the savings leverage ratio.

A savings leverage ratio greater than one means that the economic savings outweigh the cost of the derisking instruments deployed – in effect, that the derisking instruments have proved to be good value for money. The higher the savings leverage ratio, the higher the level of efficiency in terms of creating economic savings.

[151] Public costs can be discounted at a public discount rate, for example the particular country's long term sovereign lending rate.

iii. End-user Affordability

The framework's third metric, end-user affordability, takes an electricity consumer perspective and compares the generation cost (LCOE) of the solar PV in the post-derisking scenario versus the pre-derisking scenario. The unit for this metric is USD cents per kWh. The greater the percentage decrease between the LCOE for the two scenarios, the higher the efficiency of the public instrument portfolio from a rate-payer (i.e. electricity consumer) perspective.

For illustration, if a set of derisking instruments bring down the LCOE of a renewable investment from 10 units to 8 units, the derisking would have an affordability impact of 20%. Through assessing the effect of the selected instrument portfolio on electricity rates and additionally comparing the post- derisking LCOE with the baseline costs, the end-user affordability metric can prove a useful indicator of the political feasibility of spending public money on derisking instruments to support RE. Public policy change is never easy. However, a public instrument package expected to generate savings for rate-payers or increase energy access through improving the balance sheet of power utilities in developing countries is likely to face less political opposition.

iv. Carbon Abatement

The framework's fourth metric – carbon abatement – is an environmental effectiveness indicator. This metric adopts a climate change mitigation perspective by considering the carbon abatement potential and the carbon abatement costs of the RE investment. The abatement costs are calculated by dividing the present value of the incremental costs of the RE by the abatement potential. The unit for carbon abatement potential is tonnes of CO_2 equivalent over the lifetime of the RE project. The unit for carbon abatement cost is USD per tonne of CO_2 equivalent.

For illustration, assuming a pre-derisking abatement cost of 3 units per tonne of CO_2 and a post-derisking cost of 2 units per tonne of CO_2, then the abatement cost reduction is 33 percent. Note that if the incremental costs of RE are negative (i.e. RE is less expensive than the baseline energy mix), its abatement costs will also be negative. The greater the reduction in carbon abatement cost, the higher the efficiency of the policy instrument package from a climate perspective.

Annex B: Updated Electricity tariff of EAC

TYPE OF PURCHASE	TARIFF TO BE APPLIED FOR YEAR					
	2015	2016	2017	2018	2019	2020
1. ELECTRICITY SUPPLY FROM NATIONAL GRID						
Purchase at High Voltage from Grid Substation	0.1270	0.1240	0.1240	0.1240	0.1170	0.1170
Purchase at Medium Voltage from Grid Substation	0.1290	0.1260	0.1260	0.1260	0.1220	0.1220
2. ELECTRICITY SUPPLIED BY EDC IN PHNOM PENH AND KRONG TAKHMAO						
Purchase at Medium Voltage from Grid Substation	0.1595	0.1545	0.1495	0.1475	0.1350	0.1330
Industrial consumer who is connected to MV on 22kV	0.1770	0.1720	0.1670	0.1650	0.1470	0.1460
Commercial customer and administration who are connected to MV on 22kV	0.1770	0.1720	0.1670	0.1650	0.1590	0.1580
Residents, governmental organizations and embassy (>200kWh/month)	820	780	770	750	740	730
Residents consume between 51 to 200kWh/month	720	720	720	720	610	610
Residents consume between 11 to 50kWh/month	610	610	610	610	480	480
Residents consume less than 11 kWh/month	610	610	610	610	380	380
3. ELECTRICITY SUPPLIED BY EDC IN PROVINCIAL TOWNS AND RURAL AREAS						
Industrial consumer who is connected to MV on 22kV	0.1700	0.1675	0.1650	0.1640	0.1470	0.1460
Commercial customer and administration who are connected to MV on 22kV	0.1700	0.1675	0.1650	0.1640	0.1590	0.1580
Bulk sale on 22kV from sub-transmission line to distribution licensee	0.1510	0.1470	0.1450	0.1440	0.1350	0.1330
Residents, governmental organizations (>200kWh/month) in provincial towns	820	780	770	750	740	730
Residents, governmental organizations (>200kWh/month) in rural areas	820	800	790	770	740	730
Residents consume between 51 to 200kWh/month in provincial towns	820	780	770	750	610	610
Residents consume between 51 to 200kWh/month in rural areas	820	800	790	770	610	610
Residents consume between 11 to 50kWh/month in provincial towns and rural areas	820	800	610	610	480	480
Residents consume less than 10kWh/month in provincial towns and rural areas	820	480	480	480	380	380
Water pump for agriculture from 9:00 pm to 7:00 am	820	480	480	480	480	480
Schools, Hospitals and Referral Health Care Centers Connected to Public LV (rural areas)	820	800	790	770	610	610
4. ELECTRICITY SUPPLIED BY LICENCEE AND SUB-TRANSMISSION LICENCEE						
Industrial consumer who is connected to MV on 22kV	0.1725	0.1675	0.1650	0.1640	0.1470	0.1460
Commercial customer and administration who are connected to MV on 22kV	0.1725	0.1675	0.1650	0.1640	0.1590	0.1580
Bulk sale on 22kV from sub-transmission line to distribution licensee in rural areas	0.1510	0.1470	0.1450	0.1440	0.1350	0.1330
Residents (>200kWh/month), Government and Embassy	1000-3000	800	790	770	740	730
Residents consume between 51 to 200kWh/month	1000-3000	800	790	770	610	610
Residents consume between 11 to 50kWh/month	1000-3000	800	610	610	480	480
Residents consume less than 10kWh/month	1000-3000	480	480	480	380	380
Water pump for agriculture from 9:00 pm to 7:00 am	1000-3000	480	480	480	480	480
Schools, Hospitals and Referral Health Care Centers Connected to Public LV (rural areas)	1000-3000	800	790	770	610	610

Source: EAC, 2018

Annex C: References

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