INTERNATIONAL RENEWABLE ENERGY AGENCY

IRENA
International Renewable Energy Agency

Quality Infrastructure boosting PV Markets

Forum on Regional Cooperation: Developing Quality Infrastructure for Photovoltaic Energy Generation

Santiago de Chile
13-15 September 2017

International Renewable Energy Agency

1

Global and regional context

PV deployment

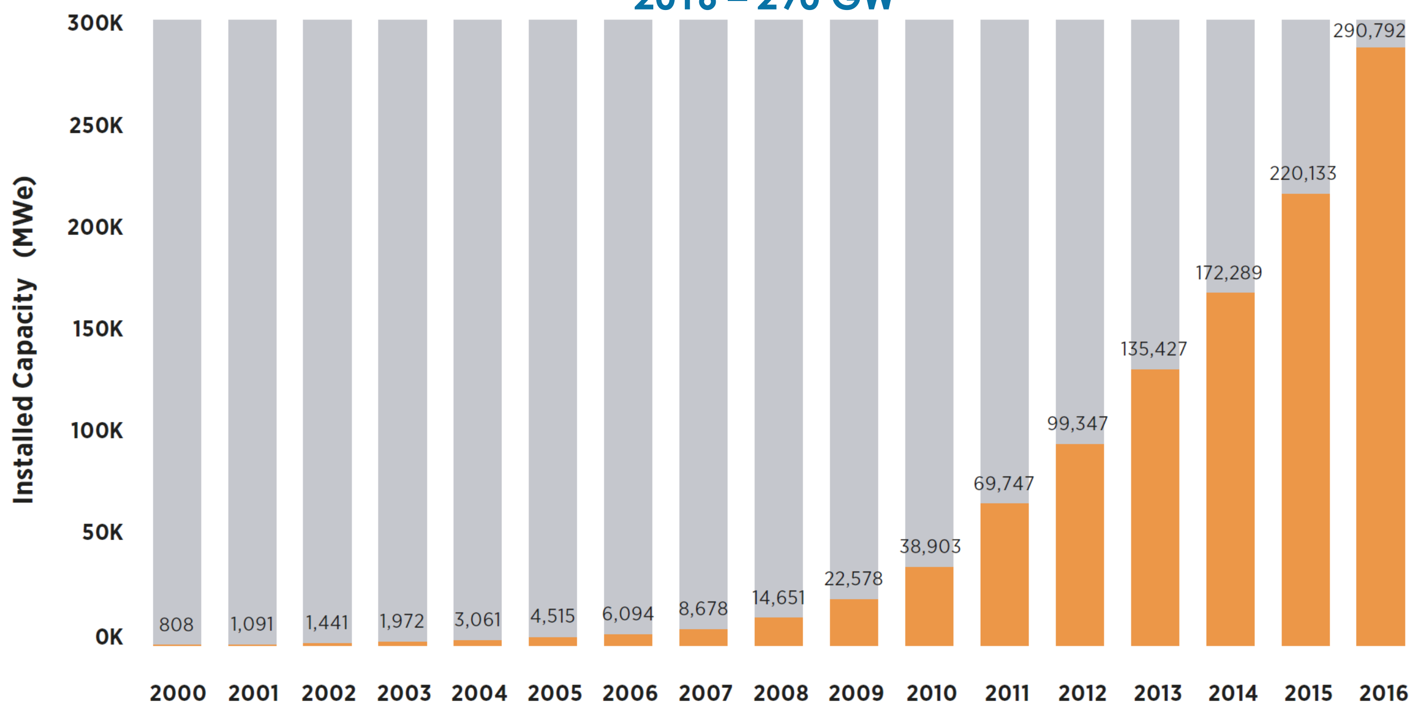
2016: A record year for renewables

IRENA
International Renewable Energy Agency

- 162 GW of RE installed – 71 GW solar, 51 GW wind, 30 GW hydro, 9 GW bioenergy, 1 GW geothermal
- USD 360 billion in investments
- RE cumulative capacity > 2,000 GW
  - Despite low oil prices
- 164 countries with RE policies in place

Cumulative installed capacity solar PV

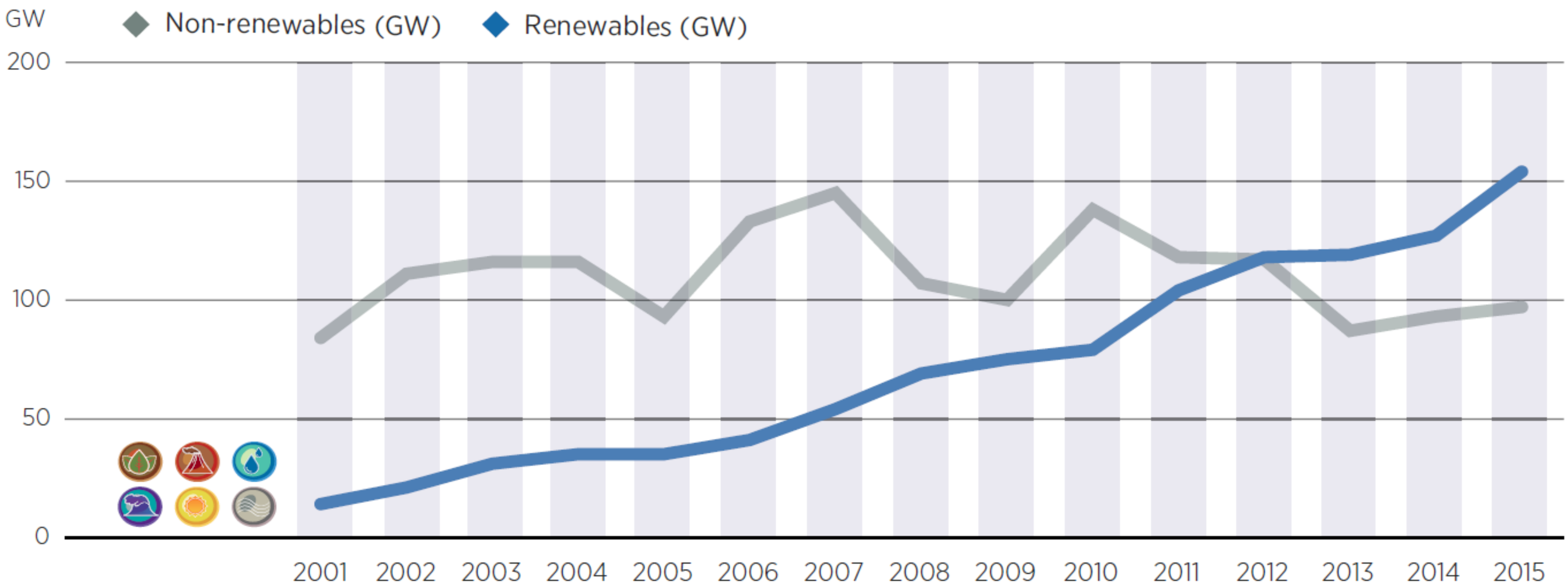
2016 – 290 GW



Investments in renewable power have surpassed the ones in fossil fuels

IRENA
International Renewable Energy Agency

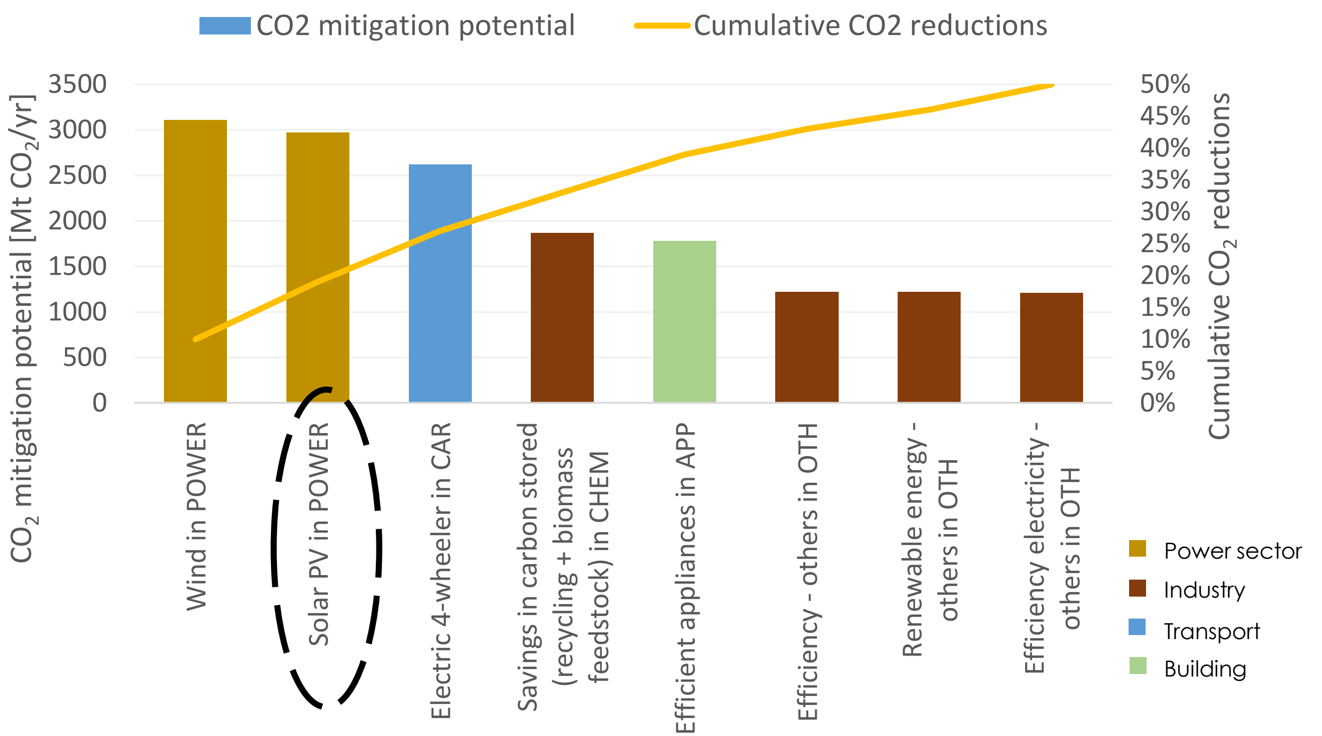
RE represents 60% of the total new capacity investments in the last two years



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Renewables (GW)	14	21	31	35	35	41	54	69	75	79	104	118	119	127	154
Non-renewables (GW)	84	111	116	116	93	133	145	107	100	138	118	117	87	93	97

CO2 impact of technology solutions

IRENA
International Renewable Energy Agency



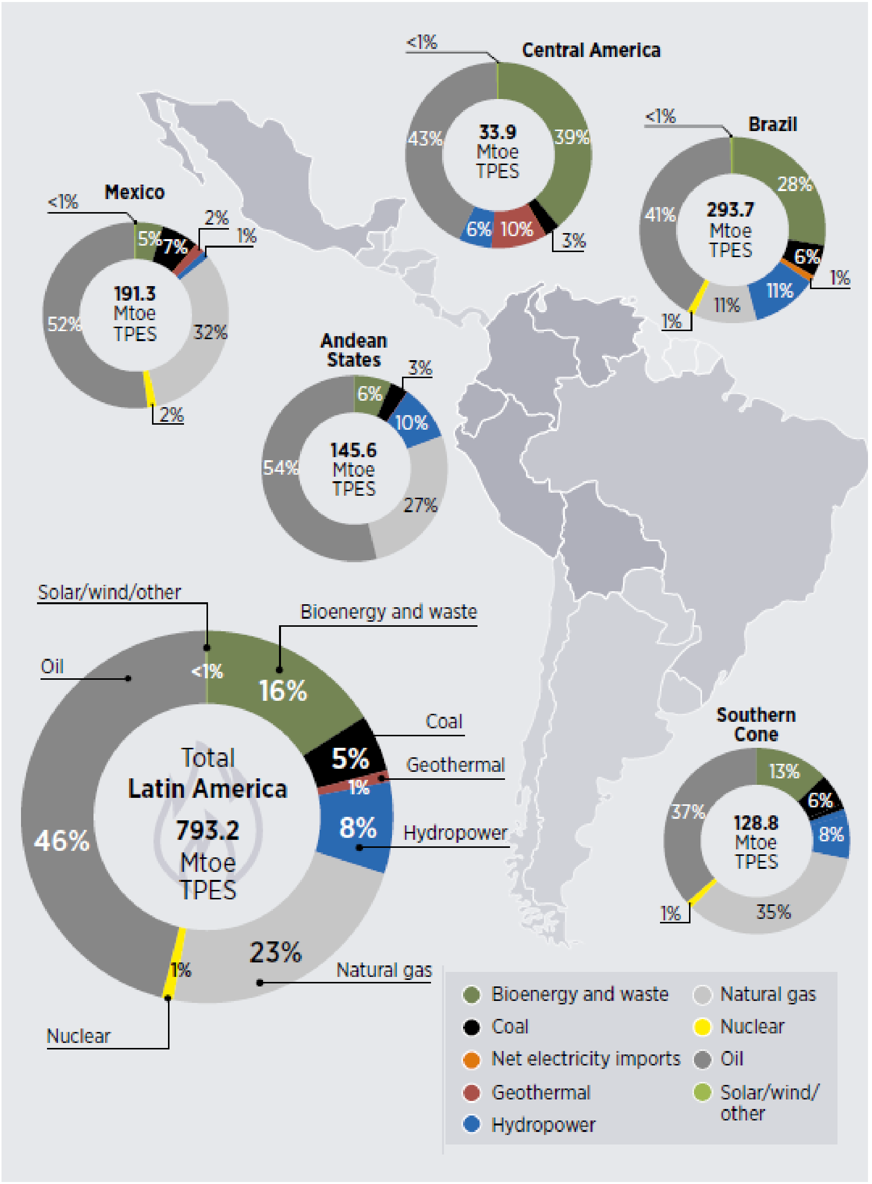
What it means for innovation?

- Wind, solar PV and EVs are the key technologies for the decarbonisations: R&D to focus on system integration and continued cost reduction
- EE technologies are available but not implemented | would regulation help?
- RE in industry is significant but cost is too high | Breakthroughs and R&D urgently needed

Top 8 technologies represent half of the total emission reductions needed. Wind, solar PV, electric mobility for passenger cars, plastics recycling and efficient appliances represent more than 1/3

Source: IRENA (2017) Accelerating the Energy Transition through Innovation

Latin America Energy Mix



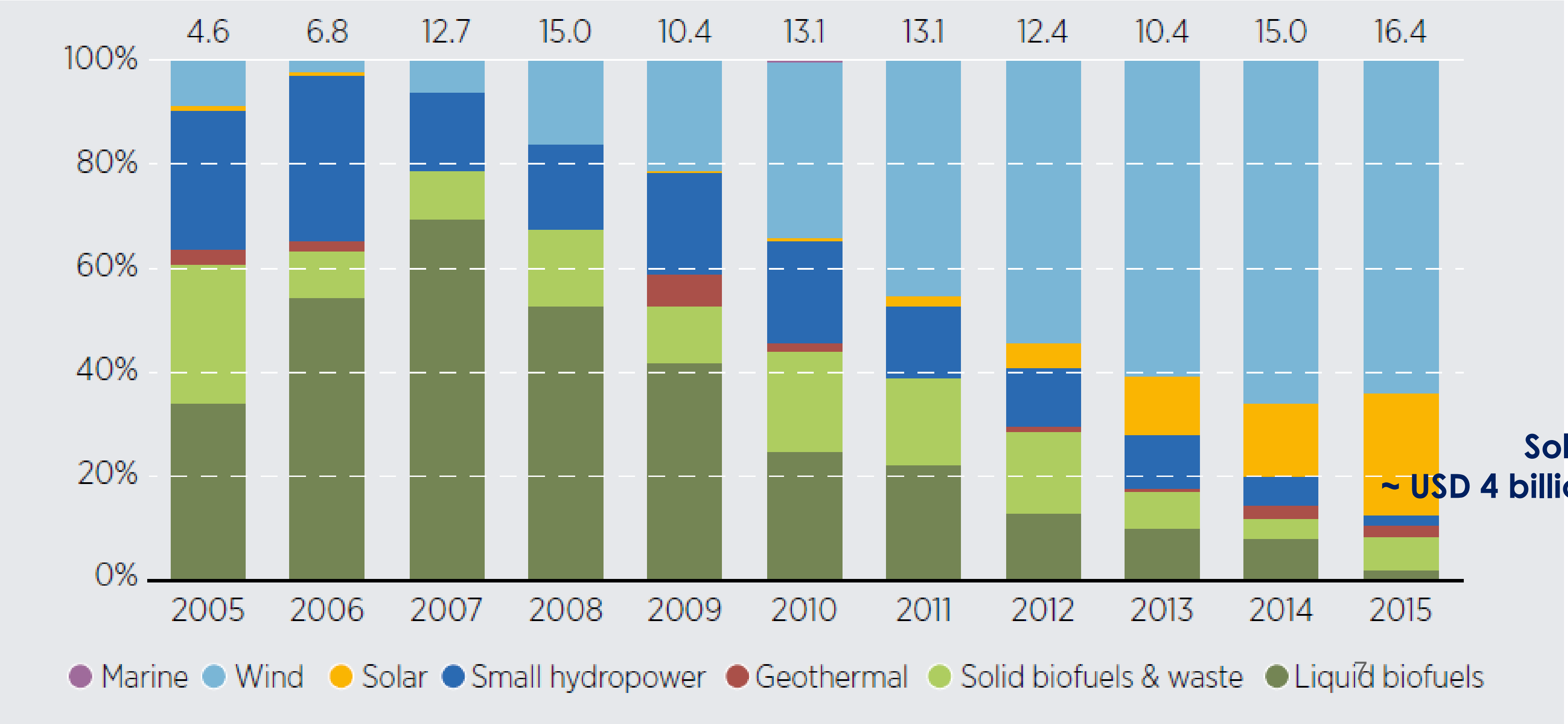
Economy based on fossil fuels yet

Source: IRENA (2016) Latin America RE Market Report

LATAM – investments per technology
Excluding large hydro

International Renewable Energy Agency

Wind and solar PV have surpassed bioenergy



Solar ~ USD 4 billion

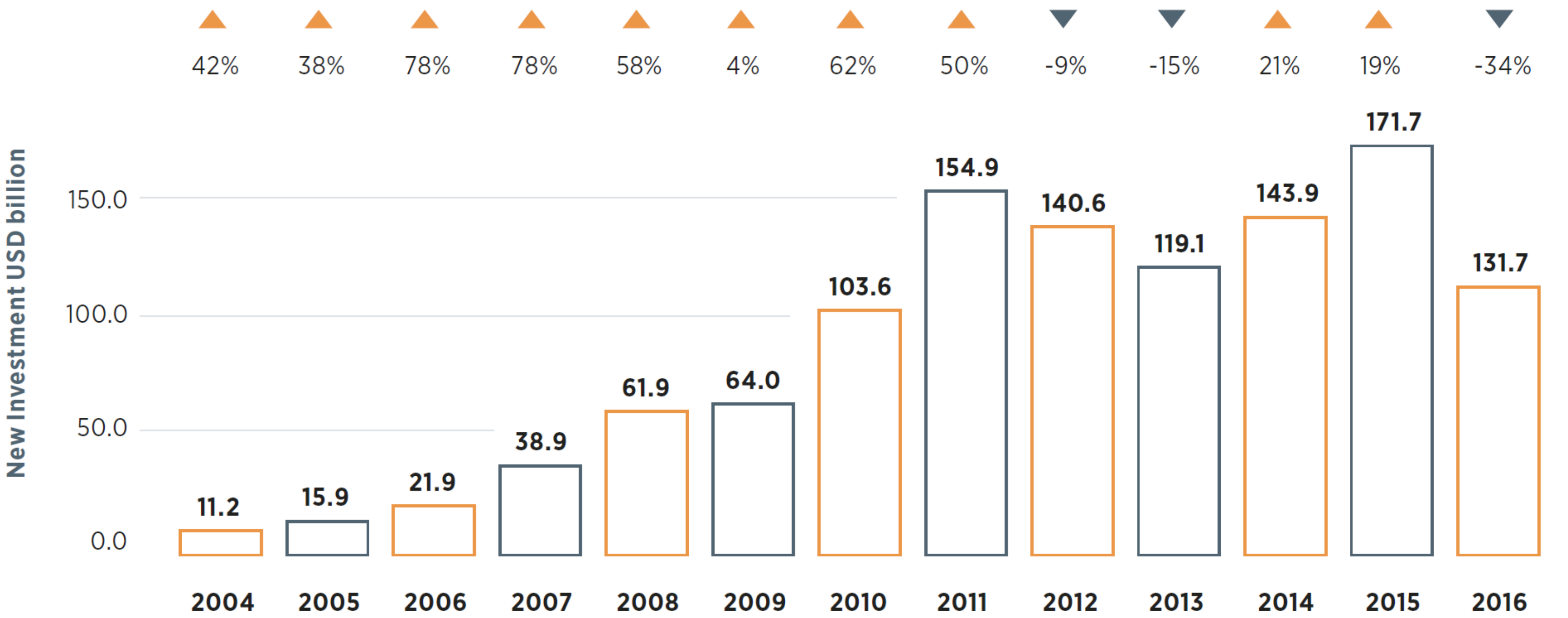
Source: IRENA (2016) Latin America RE Market Report

2

Technical risk management

Global solar power investments

IRENA
International Renewable Energy Agency

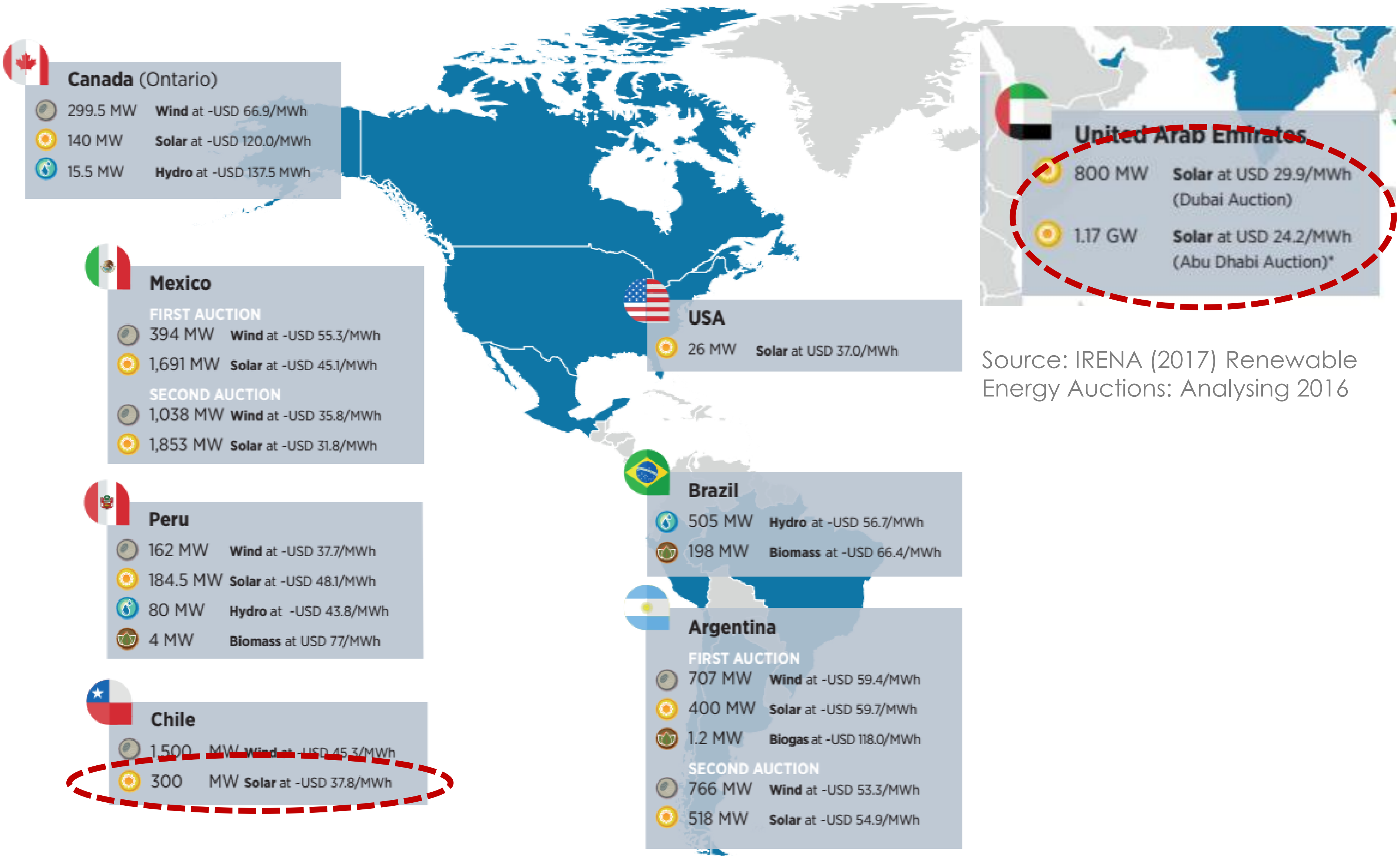


Source: Frankfurt School-UNEP Centre/BNEF. 2017.Global Trends in Renewable Energy Investment 2017, http://www.fs-unep-centre.org
Note: Investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals.

2016: **131 USD billion** 2030: **2.7 trillion USD in 15 years** | 186 billion USD/yr (1 800 GW)

Record PV prices – what will be delivered?

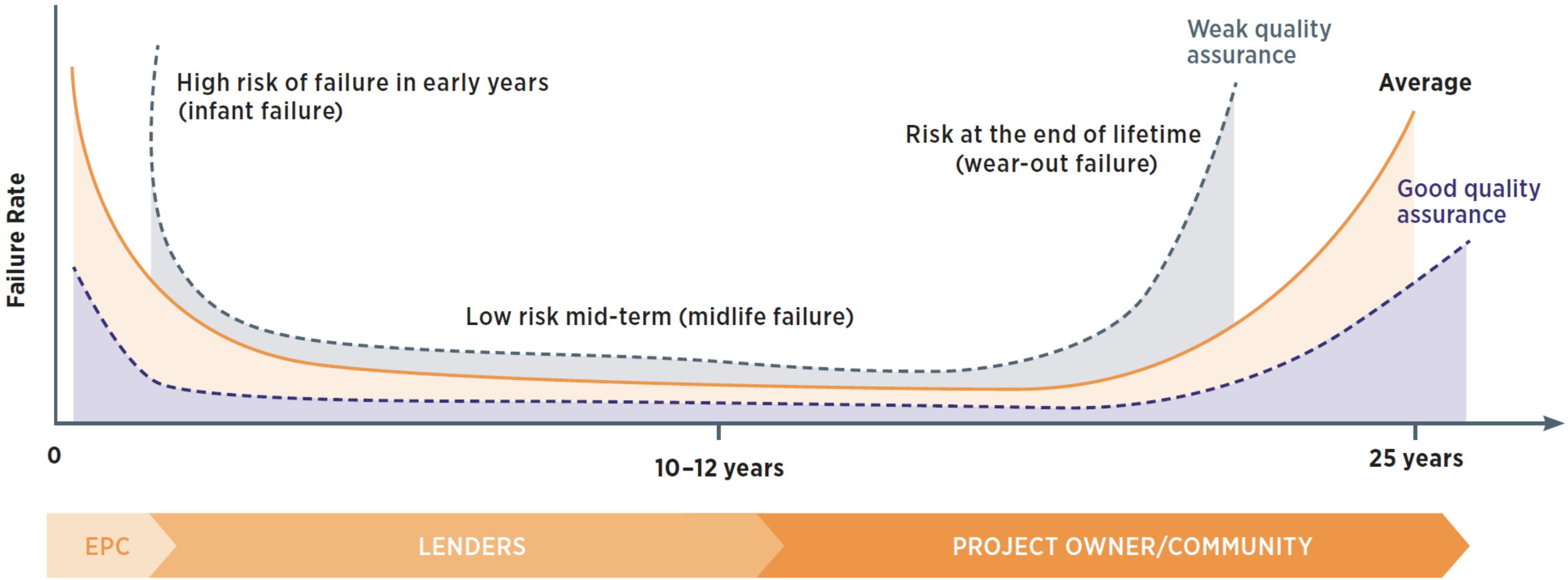
IRENA
International Renewable Energy Agency



Source: IRENA (2017) Renewable Energy Auctions: Analysing 2016

Failure risks present in their majority at early and mature stages

Life expectation of modules is 25+ years, however they have to deal with failure PV curve



Lenders' perspective: revenues only important during first 10-15 years

- Risk of infant failures are passed to EPC
- Bankability assessments further minimize risks of midlife failure
  - ✓ Valid renown certifications
  - ✓ Track record of company and modules
  - ✓ Quality of manufacturing facility
  - ✓ Warranty conditions

Holistic View - Quality Covers the Whole System, not Hardware only

Implementation of Quality Schemes covers not only equipment but whole systems
Including Design, Installation, O&M services

TÜV Rheinland

"Every other fault that we detect is due to incorrect installation."

Source: TÜV Rheinland

IRENA (2013) "International Standardisation in the Field of Renewable Energy"

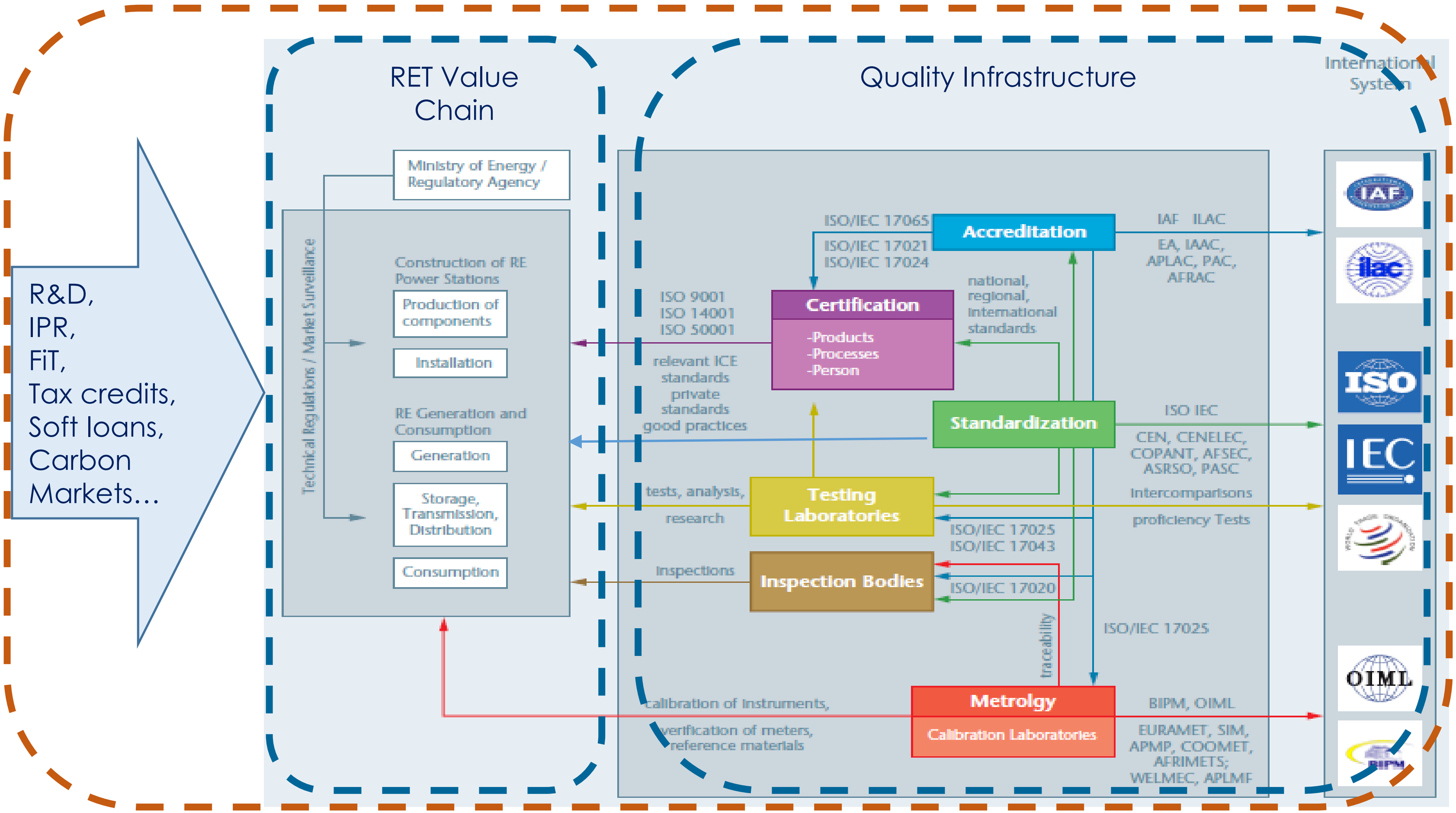
3 Quality Infrastructure

Quality Infrastructure

IRENA
International Renewable Energy Agency

Which **instruments** do we have to mitigate technical risk, attract investment and public acceptance, and meet expectations by all stakeholders in a USD trillion market?

International standards and conformity assessment schemes



Source: Physikalisch-Technische Bundesanstalt

The benefits of QI services outweigh their costs

IRENA
International Renewable Energy Agency

Quality infrastructure service	Cost	Benefit
Development: Solar resource and yield uncertainty		
Energy Production Assessment (EPA) based on measured irradiance data	Measuring local irradiance for at least one year	Reduction of uncertainty in EPA from 8% to 6% leads to an increase in P90 values by 3%. Rewarded through improved loan conditions.
Preconstruction: Prevention of low plant yields		
Batch acceptance testing for wholesale and utility projects	The cost of a batch acceptance test (Typically USD 50 000-55 350 for a 20 megawatt (MW) plant)	A reduction of the degradation rate from 0.75% a year to 0.4–0.6% a year in a project's financial model (Resulting in USD 450 000–1 000 000 of increased revenue over 25 years for a 20 MW plant)
Construction: Performance testing		
Includes independent testing in engineering, procurement and construction contracts on photovoltaic systems performance	The cost of batch testing for a 20 MW plant is USD 276.75– 553.50/MW	Photovoltaic module manufacturers deliver modules exceeding contracted performance by 2–3% when batch testing is announced. (Earning an additional EUR 4 000–6 000/MW a year increased generation for a 20 MW plant) (USD 4 428–6 642/MW/year)
Operation and maintenance		
Potential induced degradation (PID) reduction. Inspections to detect, classify and mitigate PID effects	Cost of inspection and corrective actions (for a 6 MW plant in Western Europe: EUR 2 500-–4 000/MW) (USD 2 767.5–4 428/MW)	Tackling PID reduces underperformance of 3–5%; however, recovery is not immediate (for the 6 MW plant, EUR 6 000–10 000/MW/year) (USD 6 642–11 070 MW/year)

Source: IRENA (2017) Boosting Solar PV Markets: the role of quality infrastructure

QI supporting policy-makers

IRENA
International Renewable Energy Agency

1 Policy Objectives

- Economic and affordable photovoltaic systems
- Support development goals
- Reliable photovoltaic systems
- PV integrated in power systems

2 How quality infrastructure supports the policy objectives

- Attracts investment through risk mitigation
- Increases public acceptance
- Encourages efficient services
- Fosters good practices
- Promotes consumer protection

3 Where to apply quality infrastructure

- White papers
- Guidelines
- Regulations
- Incentives
- Industry guidebooks
- Vocational Training

IRENA uses a five-stage approach for the development of QI

IRENA
International Renewable Energy Agency

International collaborations - some initiatives:

- IEC
- IEC RE
- PVQAT
- Regional
- Industry associations

What needs are coming next in QI for PV systems

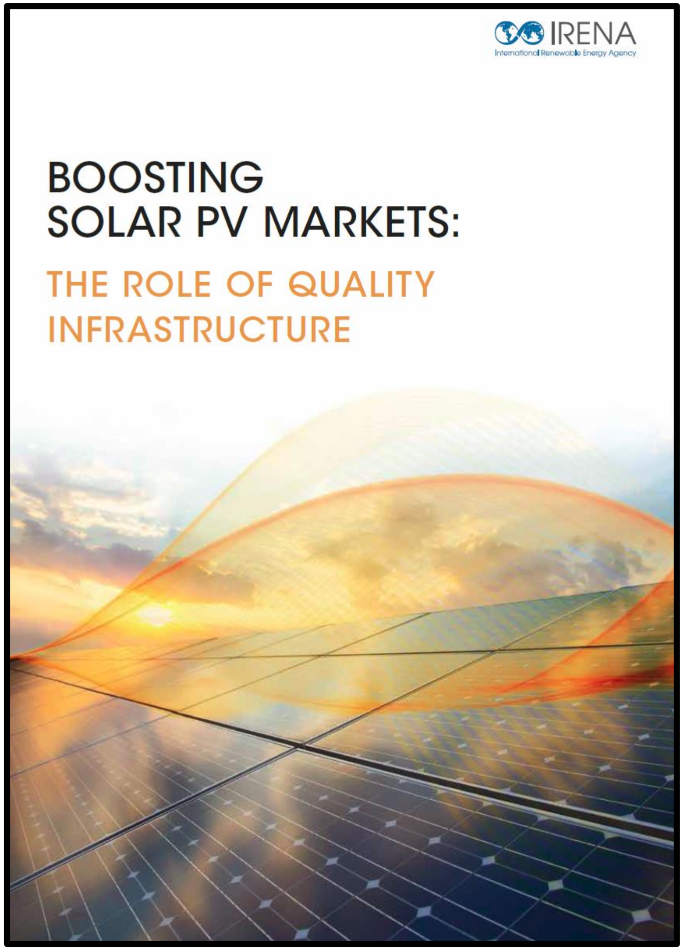
- Bankability – durability tests
- Extreme weather condition
- Life cycle aspects
- Grid integration
- New applications (e.g. floating PV, BIPV)

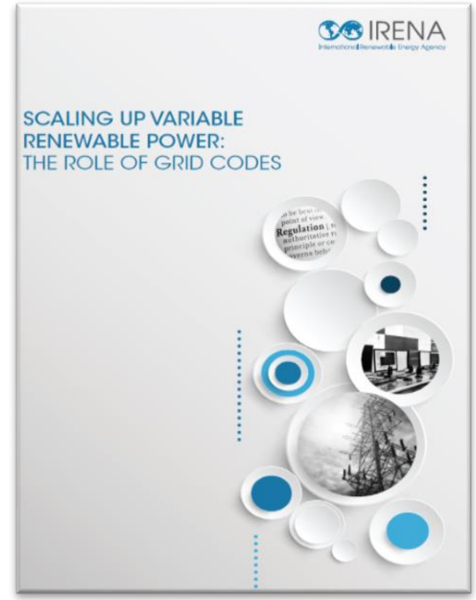
Engagement from all stakeholders in PV markets

4

IRENA Contribution

Supporting countries to develop and implement QI for RET





Download for free today:
www.irena.org/publications

IRENA - Cooperation in Quality Assurance & Standards

Requests

- ✓ **China:** Technical standards for Offshore Wind technology
- ✓ **Japan:** quality control for PV and Wind technologies in extreme weather conditions
- ✓ **Latin American region:** In cooperation with PTB, quality control for solar thermal and PV systems
- ✓ **MENA region:** In cooperation with EU GCC testing for PV systems
- ✓ **UAE:** International Standards for PV systems
- ✓ **Mauritania:** Request for support on grid connection codes
- ✓ **Colombia:** Grid codes
- ✓ **Tanzania:** Solar thermal

- ✓ **International Electrotechnical Commission - IEC:** Workshops for Countries on use of standards, INSPIRE
- ✓ **German Metrology Institute- PTB:** Quality infrastructure support, Workshop in Costa Rica, Green climate dialogue in Germany
- ✓ **ENTSO-E, SolarPower Europe and Solar United**: PV and grid codes

- ✓ **IEA PVPS Task 13:** Solar Bankability
- ✓ **WWEA:** Standards in small wind technologies

- ✓ **EU GCC Clean Energy Technology Network :** GCC Inception meeting & training-Solar Photovoltaic Testing Centres Network

5 Final remarks

Take away

International Renewable Energy Agency

- We entered into an era of low equipment cost | quality infrastructure is critical to mitigate risks and achieve the **expected LCOE**
- **Quality is not about hardware only**, but a system approach is needed
- Progress on standards and conformity assessment schemes need to **accelerate the pace** to meet the existing and NEW markets needs
- **Cost – benefit** ratio of assuring quality is positive
- International and regional **cooperation networks** strengthen and accelerate the development and implementation of QI for PV systems
- **QI supports effectiveness of policies** for PV markets – all white papers should include the role of QI

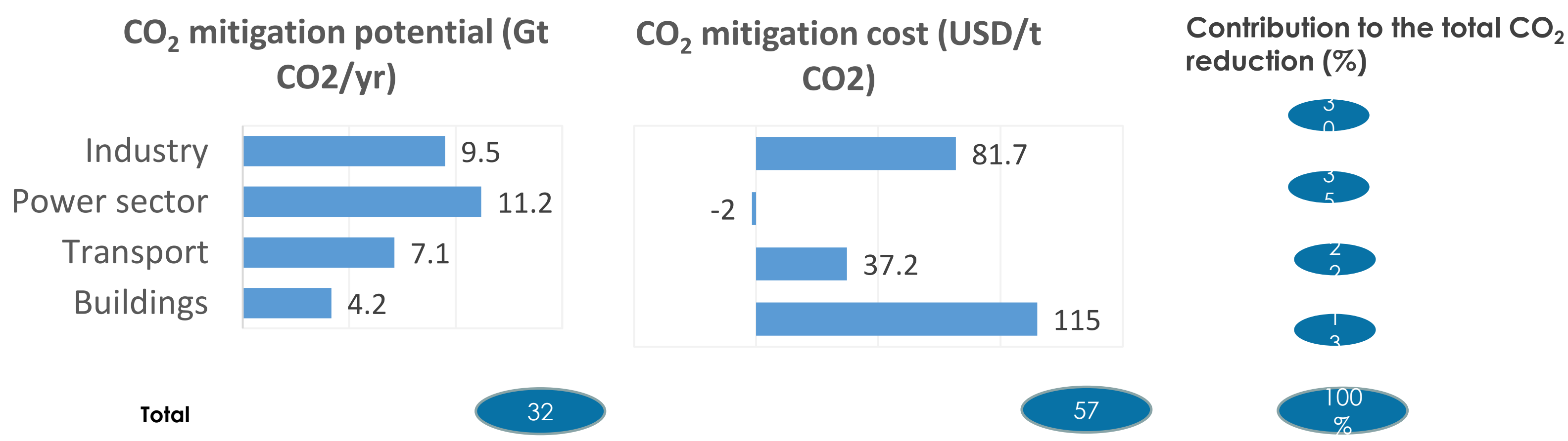
Quality pays!

Please contact:
Francisco Boshell (Fboshell@irena.org)
Alessandra Salgado (Asalgado@irena.org)
Florian Paffenholz (FPaffenholz@irena.org)

A

Backup slides for handouts

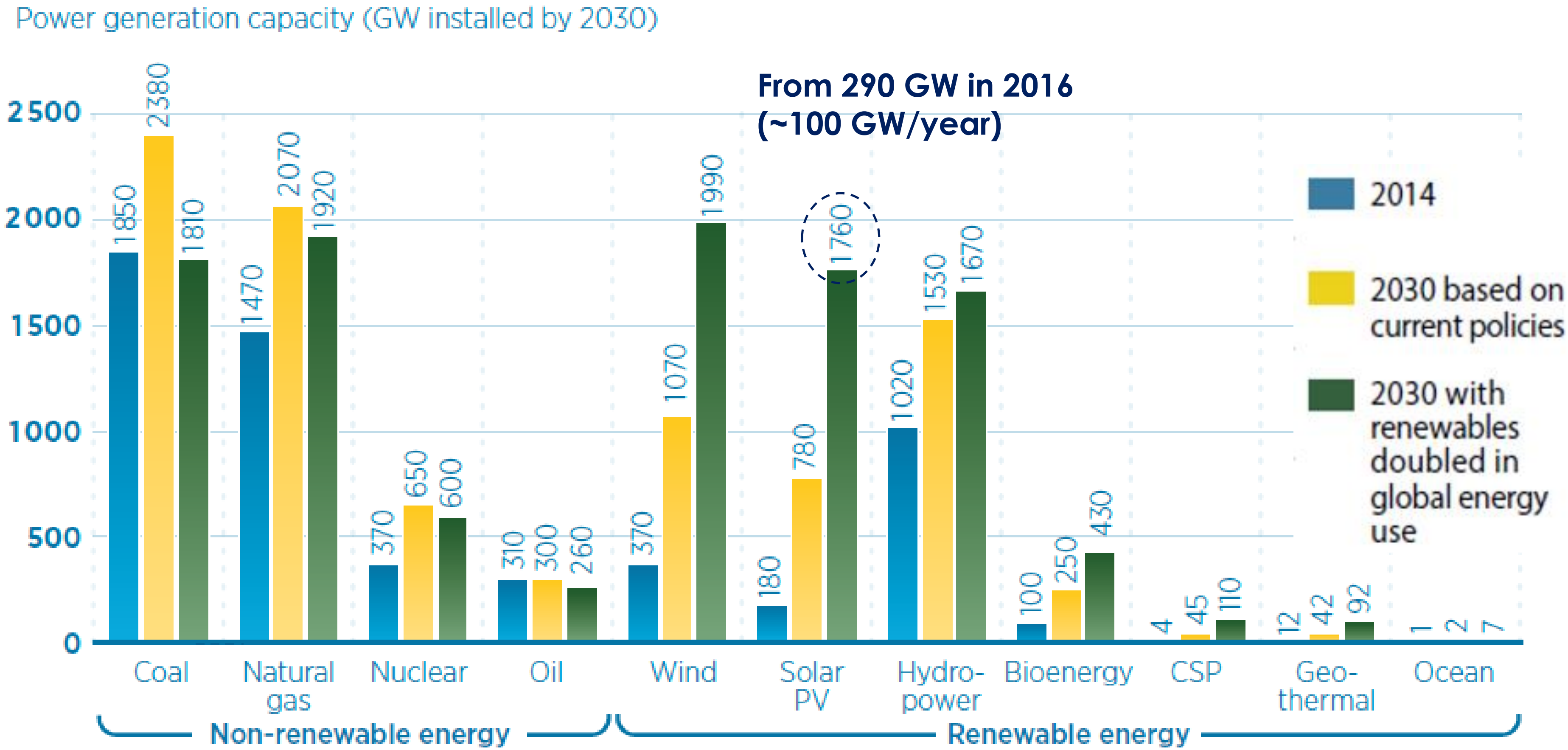
CO2 Mitigation potential and costs by sector



- Largest emission reduction potential exists in power and industry sectors
- Average abatement cost of technologies are highest in the building and industry sectors
- Options in the power sector are economically viable and for the transport sector nearly viable
- While power and transport may require continued improvement of available technologies, building and industry sectors may require breakthroughs

Growth in PV deployment

IRENA
International Renewable Energy Agency



Source: IRENA Remap 2016

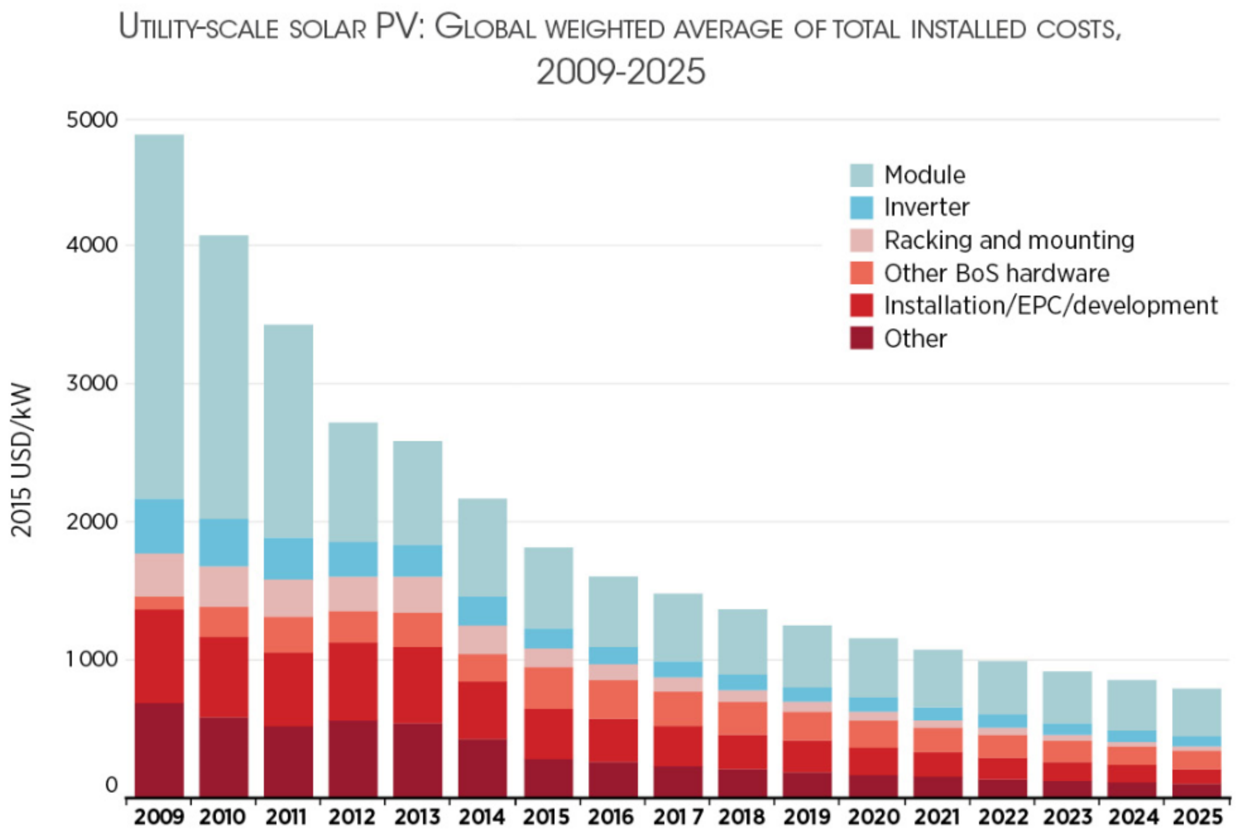
Equipment selection considering quality aspects

IRENA
International Renewable Energy Agency

PV Modules represent around a third of PV installed costs

Performance of PV modules is dependent to:

- Module technical characteristics
- Quality of materials used
- Testing procedures
- Quality of manufacturing facility
- Manufacturing process



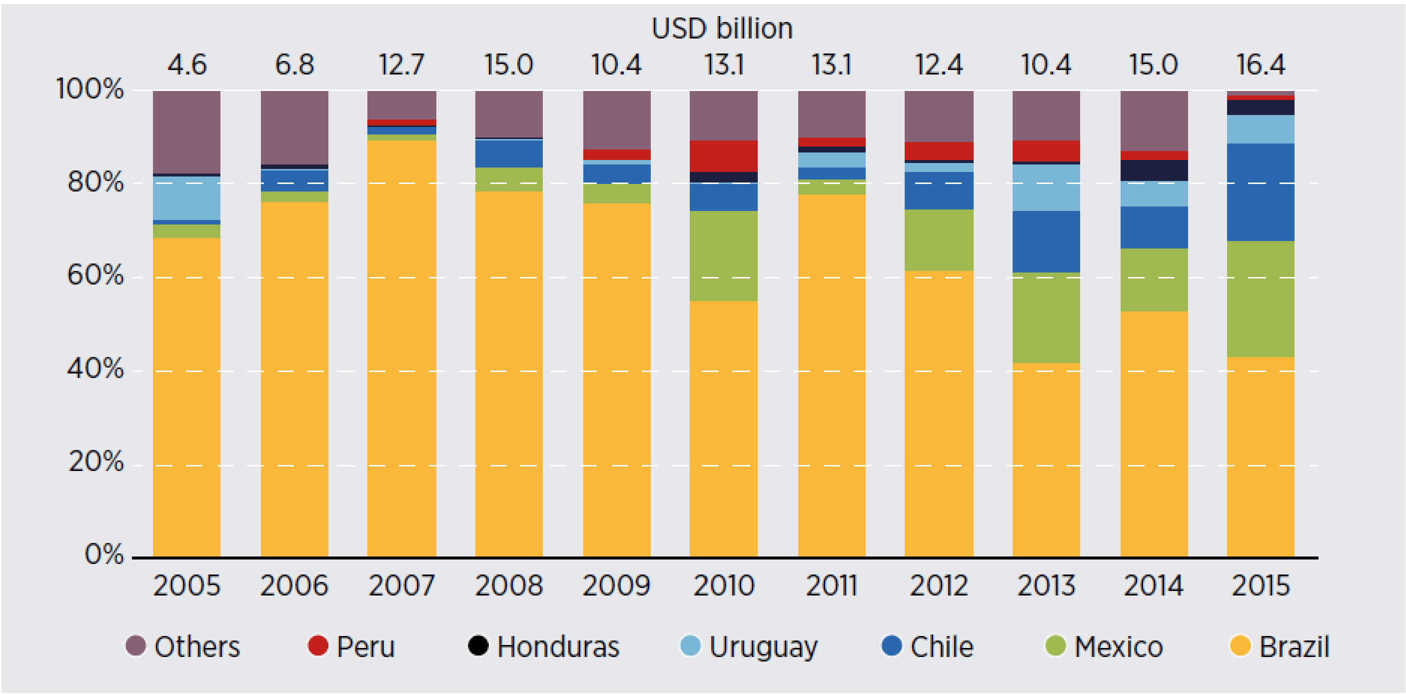
More than half of non schedule hardware repairs happen due to equipment selection

Source: IRENA (2016) Power to Change

LATAM – Inversiones por país

International Renewable Energy Agency

Brasil lidera
México, Chile y Uruguay avanzando rápidamente



Source: IRENA (2016) Latin America RE Market Report

Standards for PV systems

IRENA
International Renewable Energy Agency

System component manufacturing	System design and equipment selection	Installation and commissioning	Performance and operation & maintenance (O&M)	End-of-life
• Internationally IEC 61730, IEC 61215, IEC 62109 and IEC 62093 • IEC 61215, IEC 61646, UL 1741 and IEC 62109 • USA / UL 1703 • China has developed its own standards	• IEC 62548 (international) • IEC 62738 for large (utility) scale project • IEC 62257 for off-grid • IEC 62116 for grid-code related regulations, which is typically country specific • NEC Article 690 (USA), AS/NZS 4777,3100 (Australia) and GB 50797-2012 (China) • Rollout of national standards for installations and certification of installers	• IEC 62446 and 61724 (international)	• IEC 61724, 62446-2 (international) • ASTM E2848 (USA)	• Decommissioning and waste management options need yet to be properly addressed in international standards. • Directives, like the European Waste Electrical and Electronic Equipment (WEEE) directive, are implemented awaiting transposition into national laws and standards.

Source: IRENA (2017) Quality infrastructure for PV systems

International and National Standards

Country	PV Module	Inverter	Design and Installation	Commissio-ning	Performan-ce and Operations	Grid Code Related	Off Grid Specific	Utility Scale Specifi c
Interna-tional / IEC	IEC 61730, and IEC 61215 or IEC 61646 as applicable	IEC 62109-1/2 IEC 62093 (Qualifica tion)	IEC 62548 (Primary) and IEC 60364 series	IEC 62446	IEC 61724 Future IEC 62446-2 (2017)	Country specific, but grid function testing per IEC 62116, IEC 62910	IEC 62257 Series for off grid and rural electrifica-tion	Future IEC 62738 (2016)
USA	UL 1703 UL 61215 / IEC 61646	UL 1741, UL 62109	National Electrical Code (NEC) Article 690	Not specified, multiple industry group recommen-ded practices	ASTM E2848, multiple industry recommen-ded practices	IEEE 1547 and regional/ state require-ments	N/A	Future NEC Article 691 (2017)
Australia	Same as IEC	AS/NZS 4777, AS/NZS 3100	AS/NZS 5033	Same as IEC	Same as IEC	AS/NZS 4777	AS 4509	
China	National standards & IEC		GB 50797-2012	Same as IEC	Same as IEC			

A selection of typical PV module test lab equipment

IRENA
International Renewable Energy Agency

Equipment	Test	Description
Ambient Temperature Measurement	IEC 61215 10.3 Insulation test; 10.5 Measurement of nominal operating cell temperature (NOCT); 10.9 Hot-spot endurance test UL1703 19 Temperature test	An ambient temperature sensor, with a time constant equal to or less than that of the module(s), installed in a shaded enclosure with good ventilation near the wind sensors.
Balance	IEC 61215 10.17 Hail test	A balance for determining the mass of an ice ball to an accuracy of ± 2 %.
Irradiance Meter	IEC 61215 10.8 Outdoor exposure test; 4.10 UV preconditioning test (IEC 61215-2:2016); 4.19.3 Hot-spot endurance test (IEC 61215-2:2016)	A device capable of measuring solar irradiation, with an uncertainty of less than ± 5 %.
Pyranometer	IEC 61215 10.5 Measurement of nominal operating cell temperature (NOCT) UL1703 19 Temperature test	A pyranometer, mounted in the plane of the module(s) and within 0,3 m of the test array.
Reference Cell for measuring the light source	IEC 61215 10.2 Maximum power determination; 10.4 Measurement of temperature coefficients; 10.6 Performance at STC and NOCT; 10.7 Performance at low irradiance UL1703 20 Voltage and current measurements test	A PV reference device having a known short-circuit current versus irradiance characteristic determined by calibrating against an absolute radiometer in accordance with IEC 60904-2 or IEC 60904-6.

A selection of typical PV module test lab equipment

Equipment	Test	Description
UV Light Sensor	IEC 61215 10.10 UV preconditioning test	Instrumentation capable of measuring the irradiation of UV light produced by the UV light source at the test plane of the module(s), within wavelength ranges of 280 - 320 nm and 320 - 385 nm with an uncertainly of ±15 %.
Velocity Meter	IEC 61215 10.17 Hail test	An instrument for measuring the velocity of the ice ball to an accuracy of ± 2 %. The velocity sensor shall be no more than 1 m from the surface of the test module.
Continuity Tester	IEC 61215 10.12 Humidity-freeze test; 10.16 Mechanical load test UL1703 41 Mechanical loading test	Instrumentation to monitor the electrical continuity of the module during the test.
Resistance Measurement	IEC 61215 10.15 Wet leakage current test UL1703 27 Wet insulation-resistance test	Instrument to measure insulation resistance.
Steady-state light source	IEC 61215 10.9 Hot-spot endurance test	Radiant source 1: Steady-state solar simulator or natural sunlight capable of an irradiance of not less than 700 W·m–2 with a non-uniformity of not more than ±2 % and a temporal stability within ±5 %; or: Radiant source 2: Class C steady-state solar simulator (or better) or natural sunlight with an irradiance of 1 000 W·m–2 ± 10 %.

Methods and equipment necessary for PV system and component testing

International Renewable Energy Agency

Test	Equipment	Description
General		
Qualification test to IEC 62093	Environmental chambers	Enclosures for controlled testing of temperature, humidity
	Vibration table	Simulator with control of vibration amplitude, frequency, acceleration
	UV chamber	Enclosure for exposing equipment to controlled UV light
	Power supplies	Devices for controlling voltage and current input or output to electrical components
Inverters		
Safety tests to IEC 62109-1 and IEC 62109-2 & UL 1741 (U.S.)	PV simulator	Power supply capable of simulating current-voltage characteristics of a PV array
	Grid and load simulator	AC grid connection or simulated grid supply, and load simulators for off-grid tests
	Residual current test circuits	Resistive/capacitive circuits for validating detection of residual currents
	Environmental chambers	Enclosures for controlled testing of temperature, humidity
	Sound and sonic pressure meter	Device for measuring sound intensity (volume) and sonic pressure
	UV chamber	Enclosure for exposing equipment to controlled UV light
	Access probe	Device for determining physical access to live parts
Anti-islanding tests to IEC 62116 and IEEE 1547 (US)	PV simulator	Power supply capable of simulating current-voltage characteristics of a PV array
	Grid and load simulator	AC grid connection or simulated grid supply, and load banks to simulate electrical island
Low-Voltage Ride-Through tests to IEC 62910	PV simulator	Power supply capable of simulating current-voltage characteristics of a PV array
	Grid simulator	AC grid simulator capable of simulating full range of single and three phase voltage (collapse) with programmed durations.
Efficiency tests to IEC 61683 and IEC 62894	PV simulator/DC supply	Power supply capable of simulating current-voltage characteristics of a PV array
	AC Grid connection or simulator	AC grid connection or simulated grid supply
	Complex load banks	Controlled resistive and reactive loads, non-linear loads
	Transducers	High accuracy voltage and current measurement devices, DC and AC

Methods and equipment necessary for PV system and component testing

Test	Equipment	Description
PV charge controller		
Performance to IEC 62509	Environmental chambers	Environmental chamber is required for nearly every test in 62509 so that operational tests can be performed with the charge controller in controlled steady state temperatures.
	PV simulator/DC supply	Power supply capable of simulating current-voltage characteristics of a PV array is preferred. A controlled dc source (voltage and current) in combination with a series resistor is an acceptable alternative.
	Battery simulator/DC supply	Power supply with independent voltage and current control.
	Resistive load bank	Variable resistive load to provide controlled loads to the simulated battery and charge controller.
Combiner Boxes		
Safety and design verification to UL 1741 and IEC 61439-2	Environmental chamber	Enclosures for controlled testing of temperature, humidity.
	DC power supplies and DC voltage hi-pot tester	Controlled dc voltage and current supply for steady state testing as well as dc high pot voltage tests for validating insulating properties of components.
	DC power supply with high current capability	Supply for performing short-circuit current withstand capability tests on power components (busbars, switches, etc.)
	Radiant heat lamps	Radiant lamps are used to simulate the effects of solar radiation on various sides of the enclosure during the assembly heat-rise tests. [This test is new and will be included in the next edition of the standard.]
	Salt-mister	Salt-mist spray device used for corrosion testing of metallic parts and assemblies
	Miscellaneous environmental related test equipment	Test equipment used for mechanical impact tests (e.g. controlled hammer), controlled water and particulate sources for water and solid body ingress tests (IP ratings), etc.
	EMC test equipment	Appendix C
	Transducers	High accuracy voltage and current measurement devices, DC and AC

Methods and equipment necessary for PV system and component testing

International Renewable Energy Agency

Test	Equipment	Description
PV disconnect switches		
Safety to IEC 60947-3 or UL 98B	Environmental chamber	Enclosures for controlled testing of temperature, humidity.
	DC power supplies and DC voltage hi-pot tester	Controlled dc voltage and current supply for steady state testing as well as dc high pot voltage tests for validating insulating properties of components.
	Miscellaneous endurance related test equipment	Test equipment used for mechanical operations of switch (on/off), contact opening, mold stress relief, IP ratings, etc. .
PV Connectors		
Safety to IEC 62852 and UL 6703	Access probe for shock protection test	IEC test finger in accordance with IEC 60529.
	Corrosion test equipment	Flowing mixed gas corrosion according to test 11g of IEC 60512. Sulphur dioxide test with general condensation of moisture according to ISO 6988.
	Environmental chamber	Enclosures for controlled testing of temperature, humidity.
	Miscellaneous environmental related test equipment	Test equipment used for mechanical stresses (e.g. forced insertion and withdrawal, swing load tests) controlled water and particulate sources for water and solid body ingress tests (IP ratings), etc.
	DC power supplies and DC voltage hi-pot tester	Controlled dc voltage and current supply for steady state testing as well as dc high pot voltage tests for validating insulating properties of components.

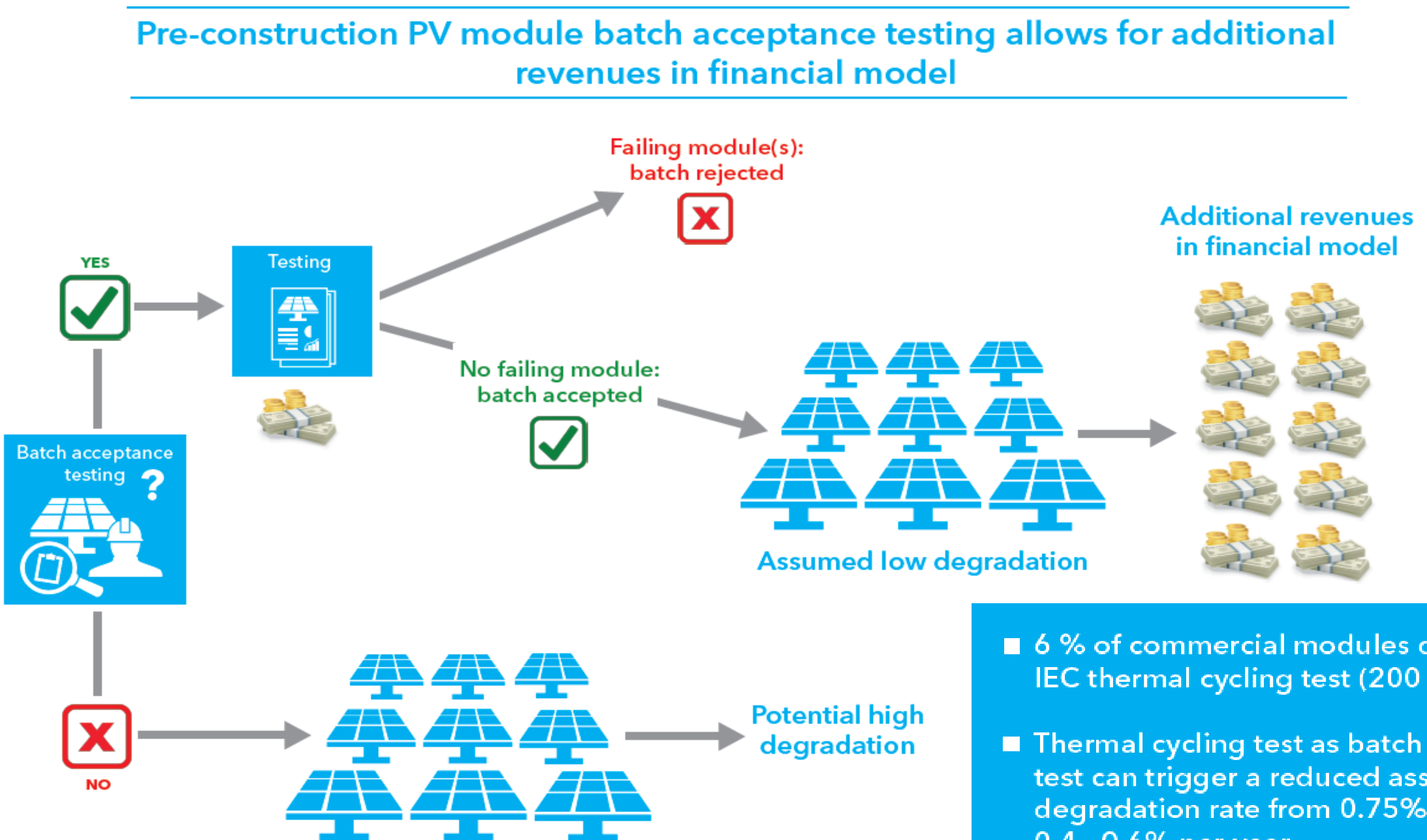
Business models for new test laboratories

- New commercial test laboratories and PV test activities are being deployed:
  - Incrementally by building on existing business activities, like those from **national universities, test institutes and engineering consultancies**
  - **Addressing solar quality issues** that are apparent in the downstream part of the PV supply chain (PV system level) and that require lower upfront investments.
  - Building upon existing business activities and/or **focusing on the downstream part of the PV supply chain** are key elements for viable business models applied by new test laboratories surviving the competitive PV market

The benefits of QI services outweigh their costs – acceptance testing

International Renewable Energy Agency

Example: batch acceptance testing



- 6 % of commercial modules do not pass IEC thermal cycling test (200 cycles)
- Thermal cycling test as batch acceptance test can trigger a reduced assumed degradation rate from 0.75% per year to 0.4 - 0.6% per year
- Higher revenues in the financial model
- Cost-benefit rate about 1:10

Different country context to develop a QI

11 Countries from Developed and Developing Countries

3 PV Systems: off-grid applications, distributed generation, and utility scale

	Utility-scale	*Distributed Generation*	*Off-grid*
Developing	Egypt Chile	China Philippines	India Tanzania
Developed	USA Germany	Singapore The Netherlands	Australia

Picture Source: Amcharts

STRATEGY TO DEVELOP AND IMPLEMENT QI - PHILIPPINES

International Renewable Energy Agency

	Utility-scale	Distributed generation	Off-grid
developing	Egypt Chile	China Philippines	India Tanzania
developed	USA Germany	Singapore The Netherlands	Australia

Context

- 2014- first E-guidebooks for both utility and rooftop PV (IEC standards for the **procurement and construction** of PV
- Standardised administrative framework for **FiT qualification**

! Challenges

1. **Regulatory barriers -** rooftop PV developers often cite the existing legal and administrative processes to be complex
2. Enhance the attractiveness of **incentive schemes**
3. Control sale of **sub-standard** PV equipment

Building on QI

- Formalisation of **"licensed" training** courses for installation
- Adoption **net metering schemes** to improve QI attractiveness
- Guidelines for **testing and certification** of PV panels

STRATEGY TO DEVELOP AND IMPLEMENT QI -TANZANIA

IRENA
International Renewable Energy Agency

Context

Tanzania Bureau of Standards (TBS)adopted :

- **IEC PV system** related standards
- Verification of Conformity of **imported products**
- **Certificates of Conformity**
- **Market surveillance.** Product fails=the importer must pay all costs relative to the removal of the products from the market.

Utility-scale	Distributed generation	Off-grid	
Egypt Chile	China Philippines	India Tanzania	developing
USA Germany	Singapore The Netherlands	Australia	developed

Challenges

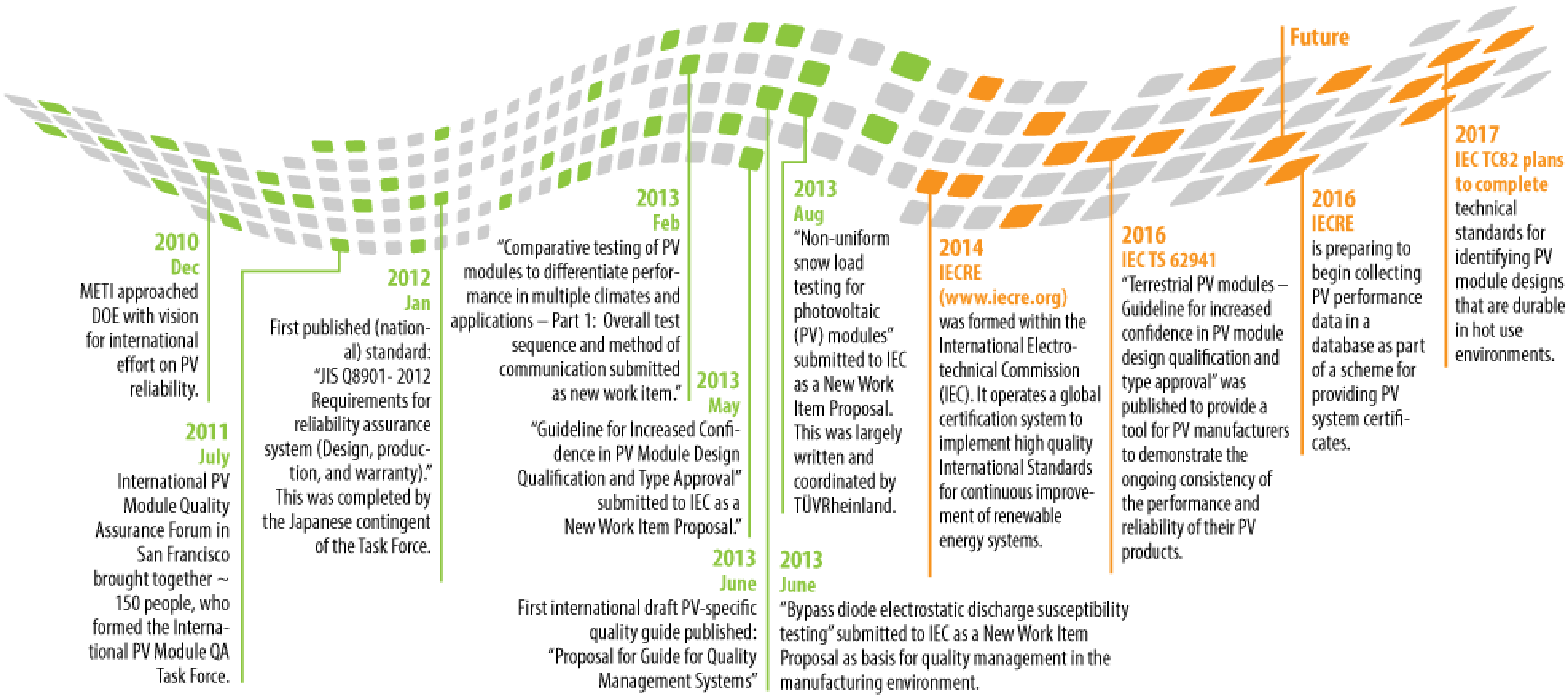
1. Parallel **counterfeit market** of substandard products developed
2. **Lack of coordination** of inter-governmental institutions

Building on QI

- Encourage **fair competition** in the market
- **Collaboration** between different institutions on control of imports
- Train importers on **technology and product registration**
- Inform **end user** on importance of selecting registered product

International PV Quality Assurance Task Force

IRENA
International Renewable Energy Agency

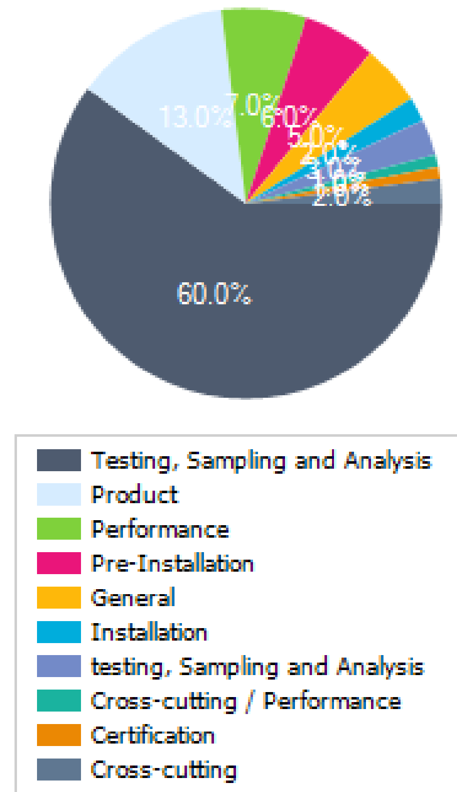


Source: PVQAT (2017)

More examples

PV installer certification	PV equipment certification
ZONNEKEUR MCS The Certification Mark for Onsite Sustainable Energy Technologies NABCEP Raising Standards. Promoting Confidence.	CLASSIFIED UL UL LISTED TÜVRheinland

INSPIRE Platform - Search of International Standards



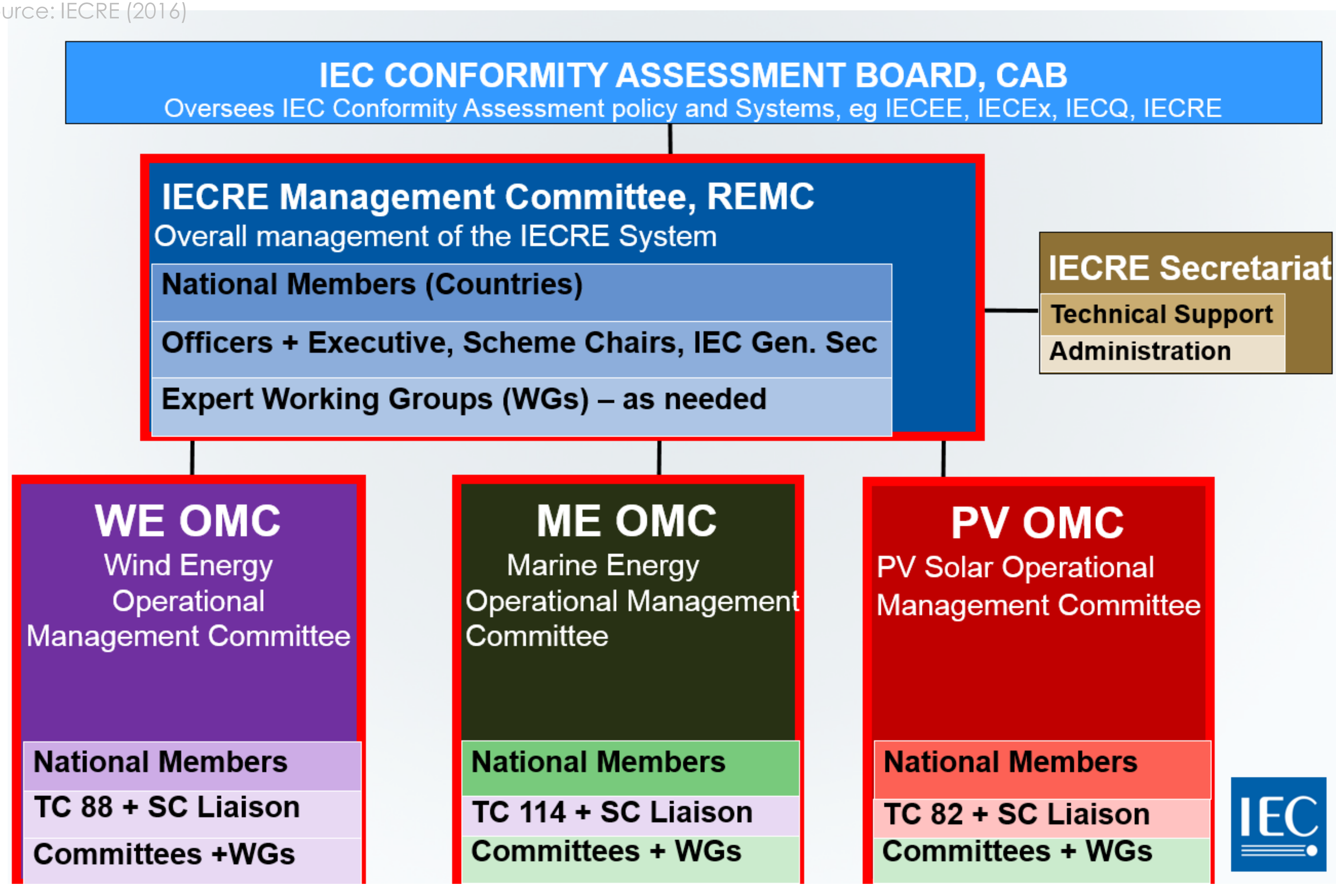
Access for free:
www.irena.org/inspire

Webinar about INSPIRE:
https://www.youtube.com/watch?v=O2AOwZH5sxM

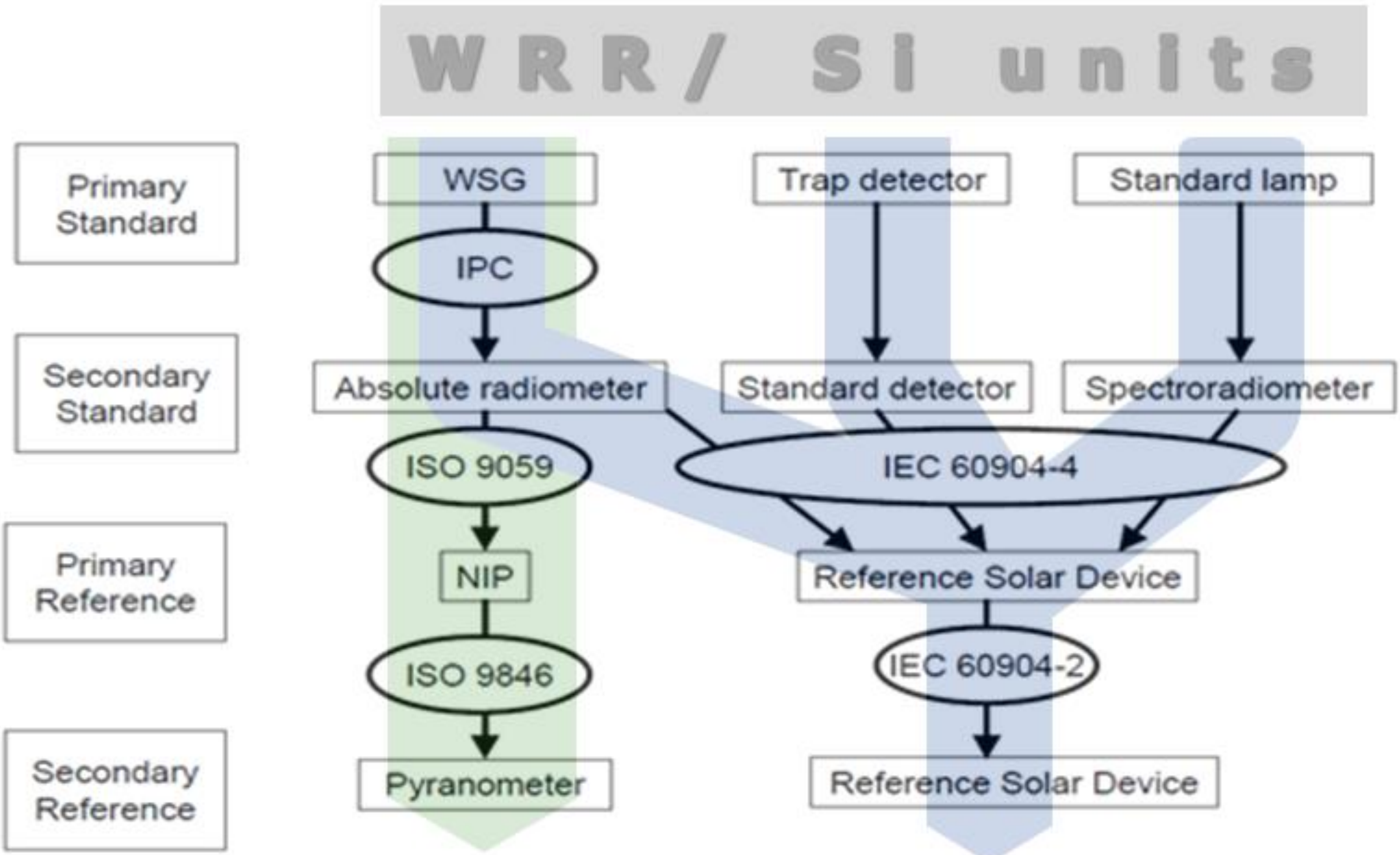
INSPIRE facilitates in a simple way a catalog of the applicable standards for Solar Technologies

IECRE Conformity Assessment System

Source: IECRE (2016)



Traceability chain for solar reference cells (blue) and pyranometer (green)



Contributions of the overall uncertainty of the energy yield

Effect	Overall uncertainty range
• Insolation variability • POA (plane of array) transposition model	• ± 4-7% • ± 2-5%
Temperature coefficients and temperature effects	± 0,02%/°C (5% relative error for crystalline silicon based modules)
Temperature deviation due to environmental conditions	1-2 °C (± 0.5-1%) Up to ±2% if environmental conditions are not included
• Inverter model • PV array model	• ±0.2% to ±0.5% for the inverter model • ±1% to ±3% for the PV array model
Degradation	± 0.25-2%
Shading	Site dependent
Soiling	± 2% (also site dependent)
Spectral Mismatch (modelled)	• ± 0.01% - 9% (depending on PV technologies) • ± 1% to ±1.5% for c-Si
Nominal power	± 1-2%
Overall uncertainty	± 5-10%

Source: (EURAC/TÜV-RH, 2016)

Summary of policies, regulations and codes for distributed PV installations

IRENA
International Renewable Energy Agency

Public policy instruments that refer to QI elements		Distributed			
		China	Singapore	Philippines	Netherlands
Conformance	Guidelines and guidebooks		✓	✓	
	Development of national standards	✓	✓		
Compliance	Adoption of standards (PV components)	✓	✓		
	Adoption of standards (Installation)		✓		
	Testing of PV modules and components	✓			
	Formal training requirements, installer certification				✓
	Certification of grid code compliance	✓	✓	✓	✓
	Penalties for non-compliance	✓	✓		✓

Summary of policies, regulations and codes that refer to QI for utility PV installations

Public policy instruments that refer to QI elements		Utility			
		USA	Egypt	Chile	Germany
Conformance	Guidelines and guidebooks	✓			✓
	Development of national standards	✓		✓	✓
Compliance	Adoption of standards (PV components)	✓			
	Adoption of standards (Installation)				
	Testing of PV modules and components	✓			
	Formal training requirements, installer certification	✓			
	Certification of grid code compliance	✓	✓	✓	✓
	Penalties for non-compliance	✓			

Summary of policies, regulations and codes that refer to off-grid PV installations

International Renewable Energy Agency

Public policy instruments that refer to QI elements		Off-grid		
		Australia	India	Tanzania
Conformance	Guidelines and guidebooks	✓	✓	✓
	Development of national standards	✓		
Compliance	Adoption of standards (PV components)	✓	✓	✓
	Adoption of standards (Installation)	✓		
	Testing of PV modules and components	✓		✓
	Formal training requirements, installer certification	✓		
	Certification of grid code compliance	NA	NA	NA
	Penalties for non-compliance	✓	✓	✓

Quality is a key aspect to mitigate environmental impact

IRENA
International Renewable Energy Agency

High failure rates lead to a significant amount of waste

In Germany:

1 MW represents approximately 100 tons of waste
Current installed capacity is 40 GW = 4 million tons

With ca. 1% failure = 40K tons of additional waste to be disposed

The QI Payback

- Positive Energy Balance
- Higher revenues
- Consumers protection
- Mitigate Carbon Footprint

Source: Adapted from Solar World 2016

Work-in-progress at international level

International Renewable Energy Agency

	Durability Testing	Value Chain
Gap	Not assure PV systems last as long as **expected project lifetime** (20+ years)	**Further International standards** in installation, operation, maintenance, documentation and decommissioning, end of life.
Possible Solution	**Stringency** of test methods? Private sector can incorporate **batch acceptance testing** in large wholesale procurements or utility scale projects.	Encourage QI addressing the **entire PV life-cycle**

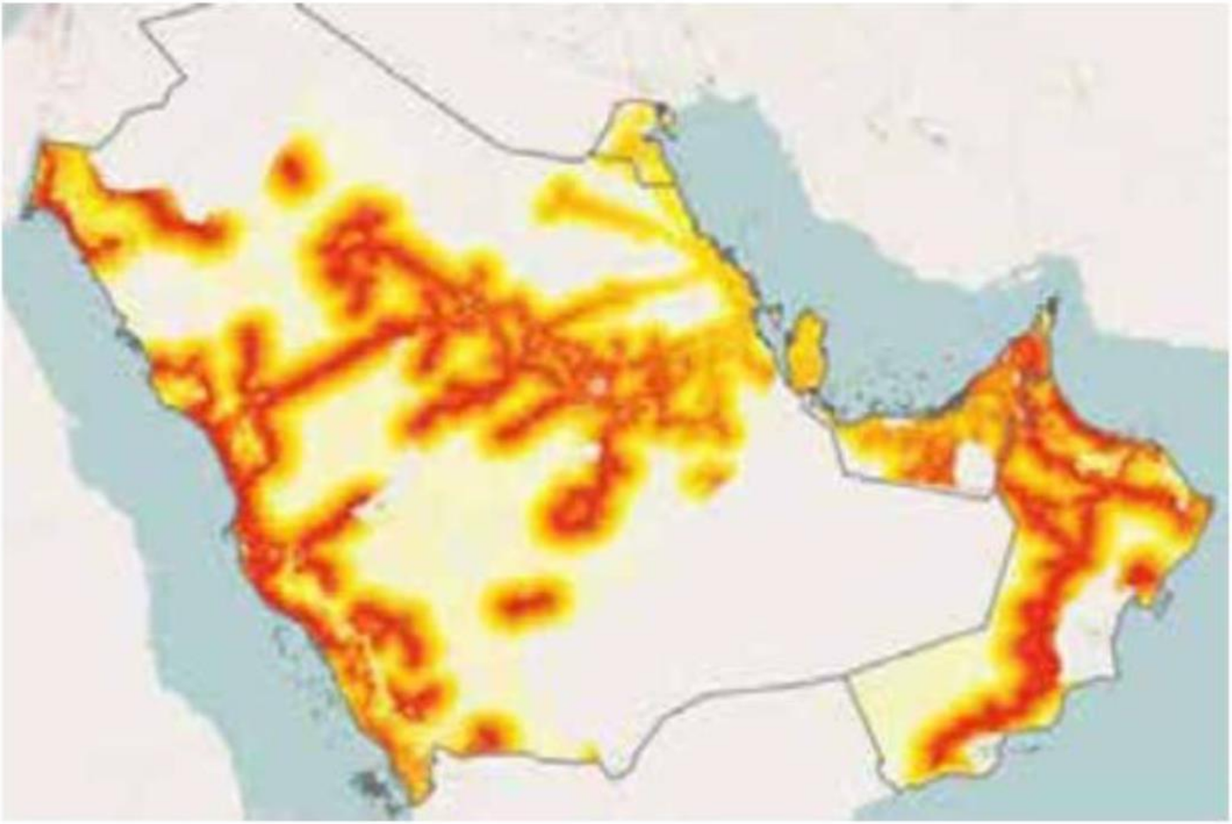
Source: IRENA (2017) Quality infrastructure for PV systems

Extreme weather conditions: Example – GCC region

IRENA
International Renewable Energy Agency

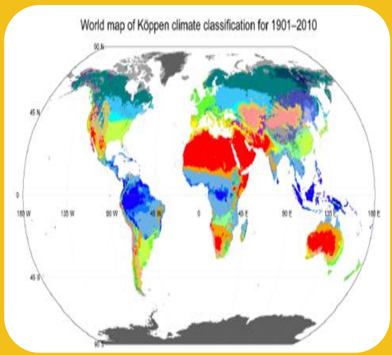
~60% of the GCC's surface area has excellent resources for solar PV
Just 1% of this area represents ~470 GW of additional capacity

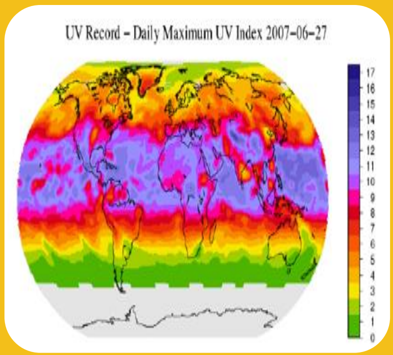
- Source: IRENA (2016) RENEWABLE ENERGY MARKET ANALYSIS: THE GCC REGION



Source: (IRENA, 2016) (http://irena.masdar.ac.ae/?map=2146)

GCC's local conditions





Temperature: IEC open air conditions (-40oC - +40oC) | GCC -20oC - +55oC high humidity

Annual irradiance: Germany ~1 200 kWh/m2 | GCC ~2 300 kWh/m2 – UV double

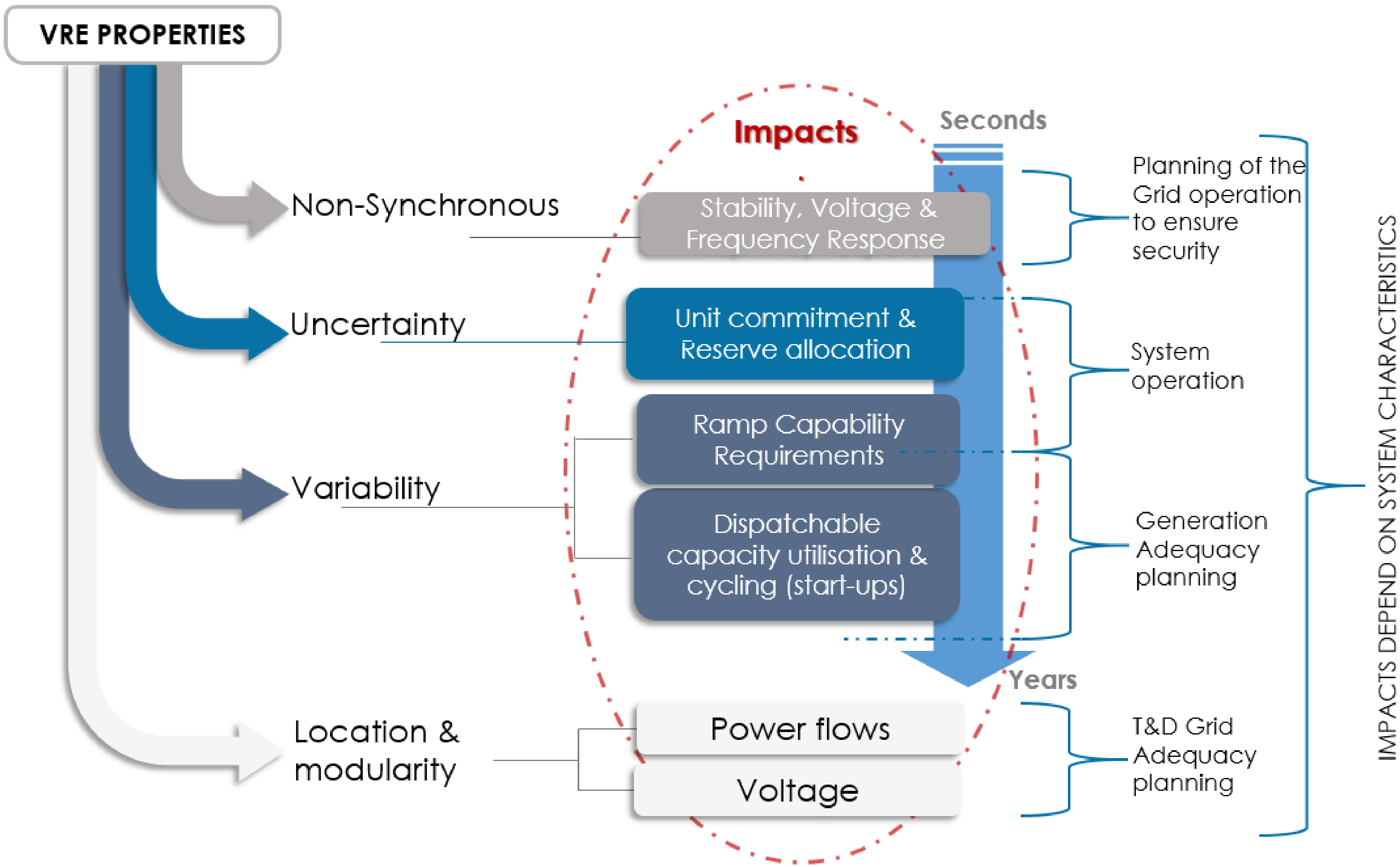
Hail: IEC 25mm Ø | GCC 44mm Ø

Sand: no international test methods – different types of sand

Sources: hanschen.org; promote.fmi.fi; arabnews.com; KACST

Standards for grid integration – Grid codes

IRENA
International Renewable Energy Agency



Source: IRENA

New applications

IRENA
International Renewable Energy Agency

BIPV

BS EN 50583-2:2016

Photovoltaics in buildings

Part 2: BIPV systems

Floating PV

Table 2 — Mounting categories A – E

Category A:	**Sloped, roof-integrated, not accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle between 0° and 75° (see Fig. 1) with a barrier underneath preventing large pieces of glass falling onto accessible areas below	
Category B:	**Sloped, roof-integrated, accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle between 0° and 75° (see Fig. 1)	
Category C:	**Non-sloped (vertically) mounted not accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of between and including both 75° and 90° (see Fig. 1) with a barrier behind preventing large pieces of glass or persons falling to an adjacent lower area inside the building.	
Category D:	**Non-sloped (vertically) mounted accessible from within the building**	
	The PV modules are mounted in the building envelope at an angle of between and including both 75° and 90° (see Fig. 1)	
Category E:	**Externally integrated, accessible or not accessible from within the building**	
	The PV modules are mounted onto the building and form an additional functional layer (as defined in 3.1) exterior to its envelope (e.g. balconies, balustrades, shutters, awnings, louvres, brise soleil etc.).	

Sources: BSI Group | http://www.japanbullet.com/technology/west-holdings-to-build-japan-s-largest-floating-solar-power-plant