Innovation Landscape for the Sustainable Energy Transition

Jaidev Dhavle

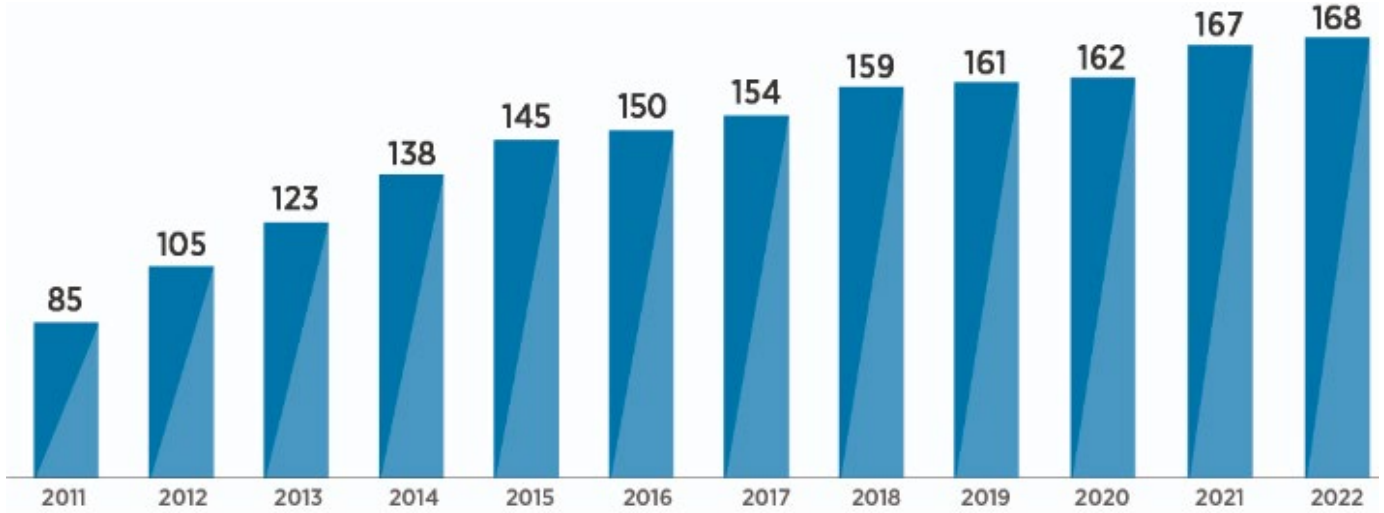
WIPO Symposium: Accelerating the Imperative: Green Technology Deployment

01 November 2023

IRENA Key Facts

- Established in 2011
- Headquarters in Masdar City, Abu Dhabi, UAE
- IRENA Innovation and Technology Centre – Bonn, Germany
- Permanent Observer to the United Nations – New York, USA

168 Members and 16 States in Accession



Mandate

To promote the widespread adoption and sustainable use of **all forms of renewable energy** worldwide

Bioenergy

Geothermal Energy

Hydropower

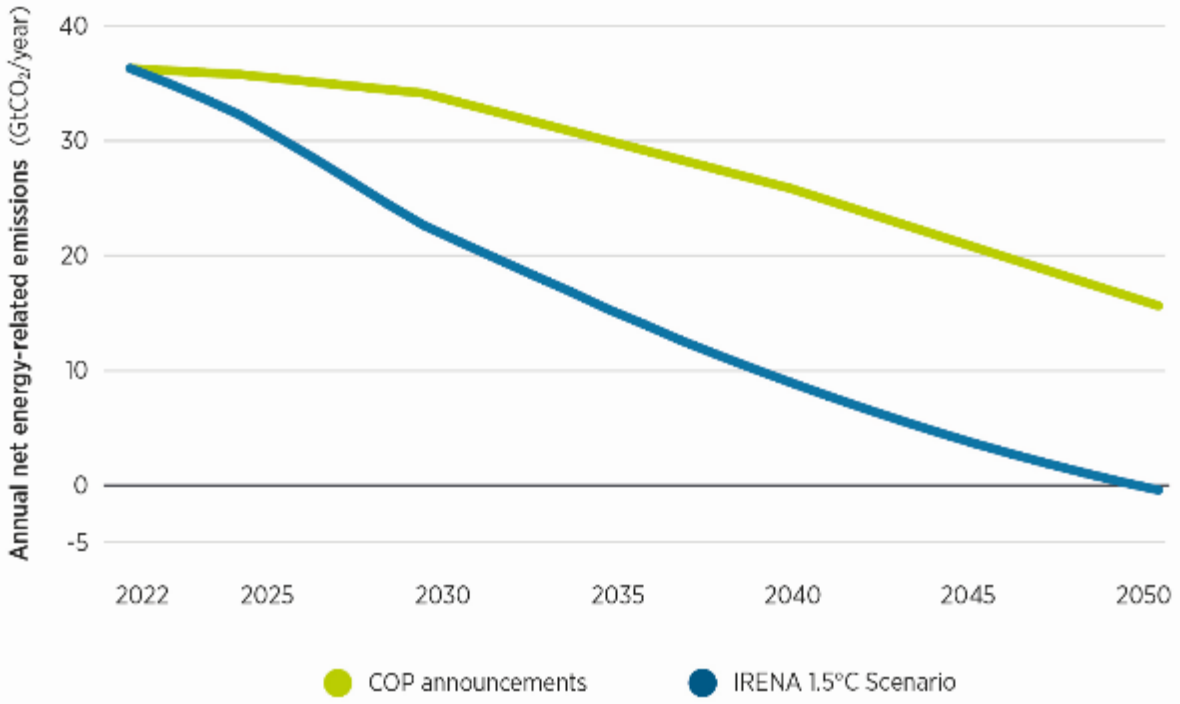
Ocean Energy

Solar Energy

Wind Energy

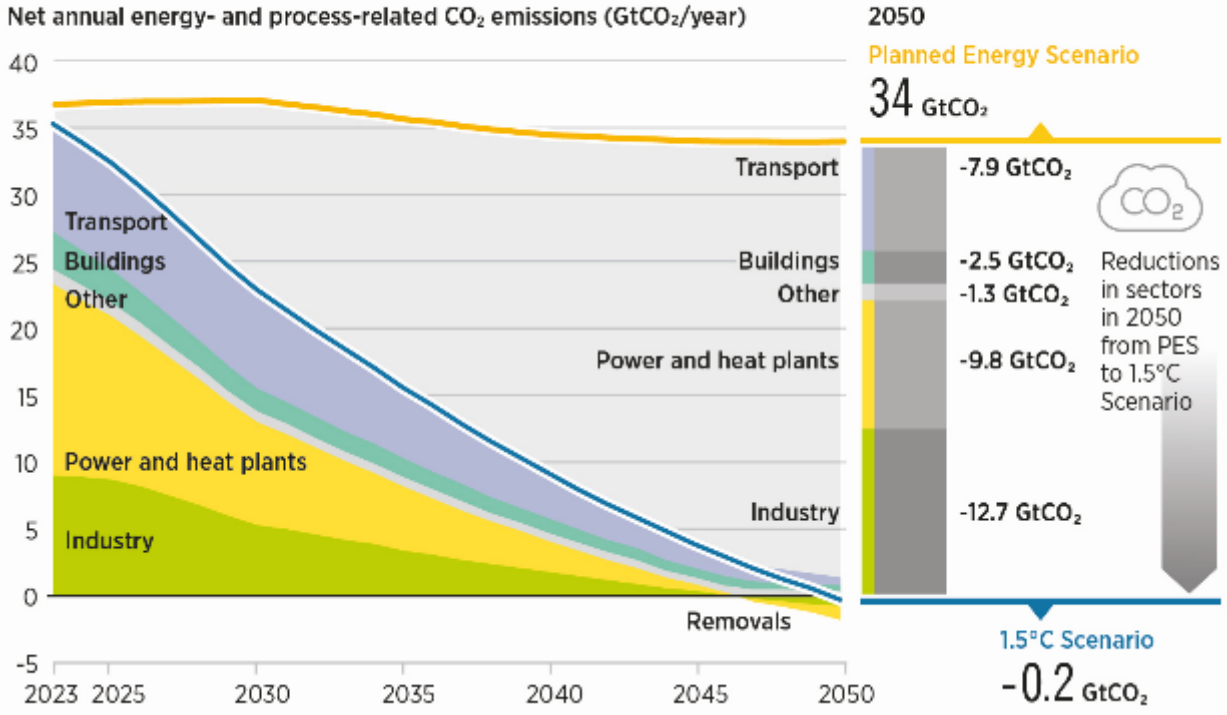
Energy Transition is off-track: NDCs and net zero pledges

FIGURE 1.6 CO_2 emission trajectories based on COP announcements and the 1.5°C Scenario



Notes: COP announcements trajectory calculated based on data from: (Meinshausen et al., 2022). COP = Conference of the Parties (United Nations Climate Change Conference); GtCO2 = gigatonne of carbon dioxide.

FIGURE 1.4 Estimated trends in global CO_2 emissions under the Planned Energy Scenario and 1.5°C Scenario, 2023-2050

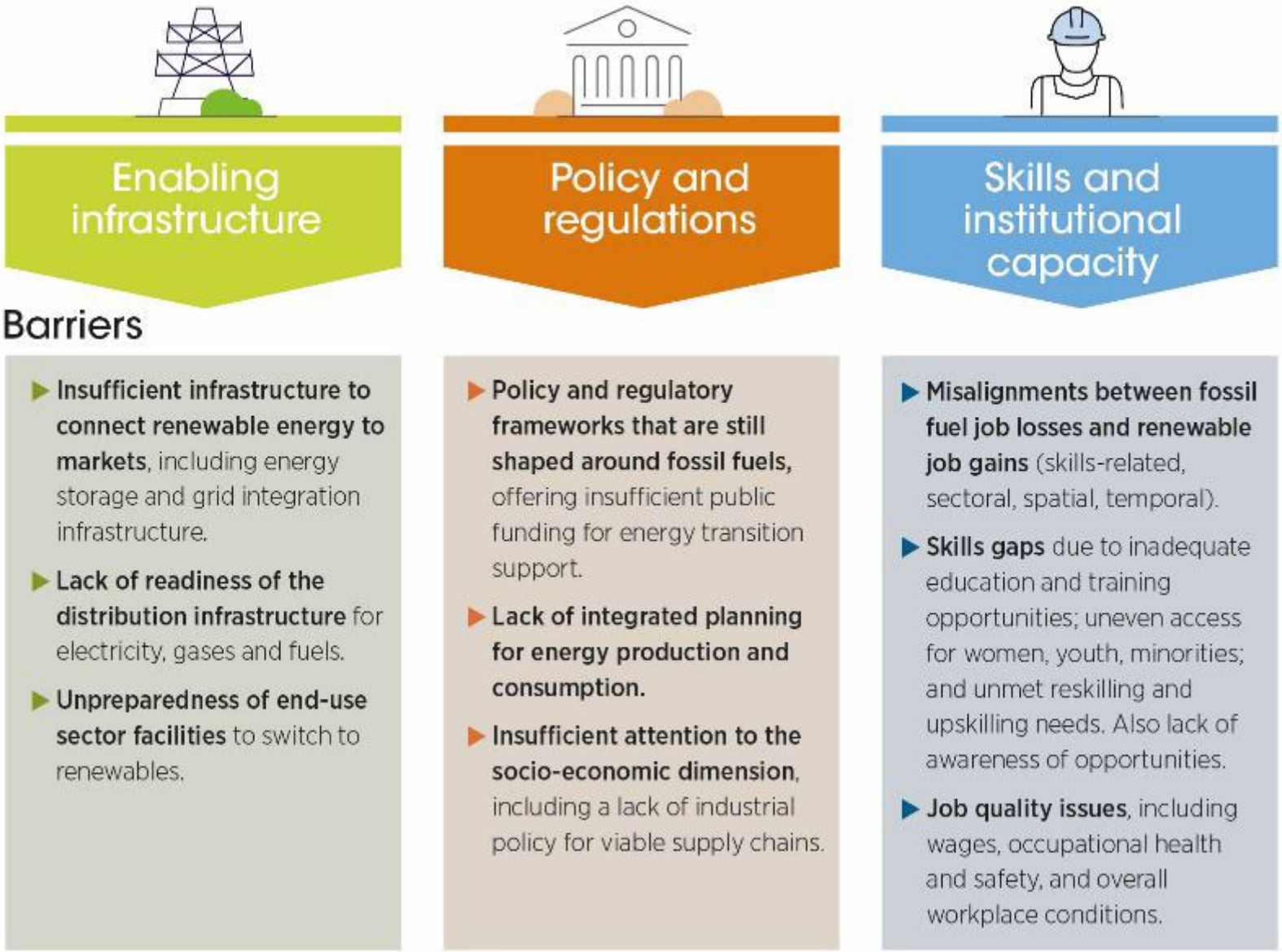


Notes: GtCO2 = gigatonne of carbon dioxide; PES = Planned Energy Scenario.

- Despite the increased ambition expressed in COP27 announcements, current climate pledges are **insufficient** to reach **net zero** by mid-century
- Although the mitigation ambition level was clearly raised at COP27, substantial additional efforts are required **to bridge the gap** towards the 1.5˚C target
- Emissions gap in 2050 between the **COP27** announcements trajectory and the **1.5˚C Scenario** is still **16 Gt**

Source: IRENA WETO 2023

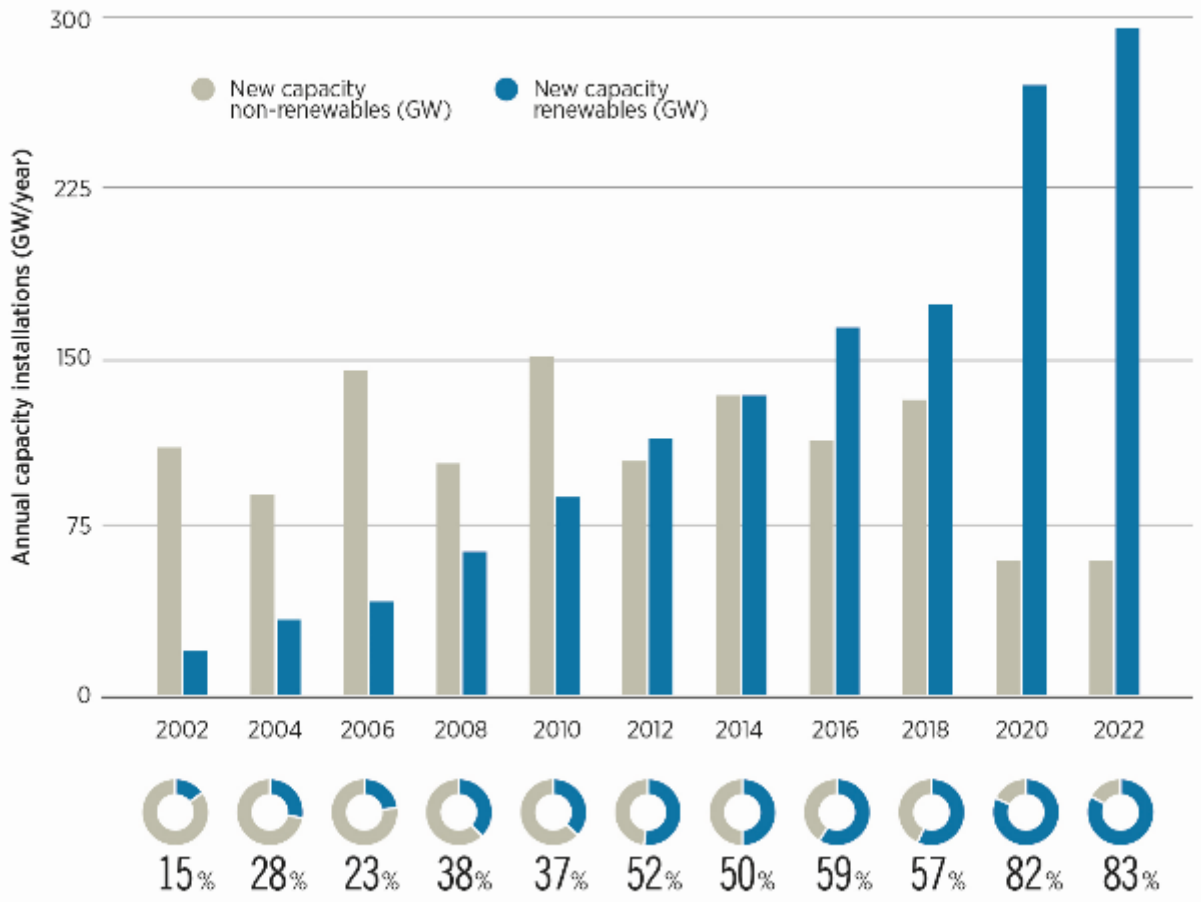
Key Barriers hampering the Energy Transition



Source: IRENA WETO 2023

Good News: Rapid scale up of RE-based generation capacity since 2010

FIGURE 2.1 Annual power capacity expansion, 2002-2022



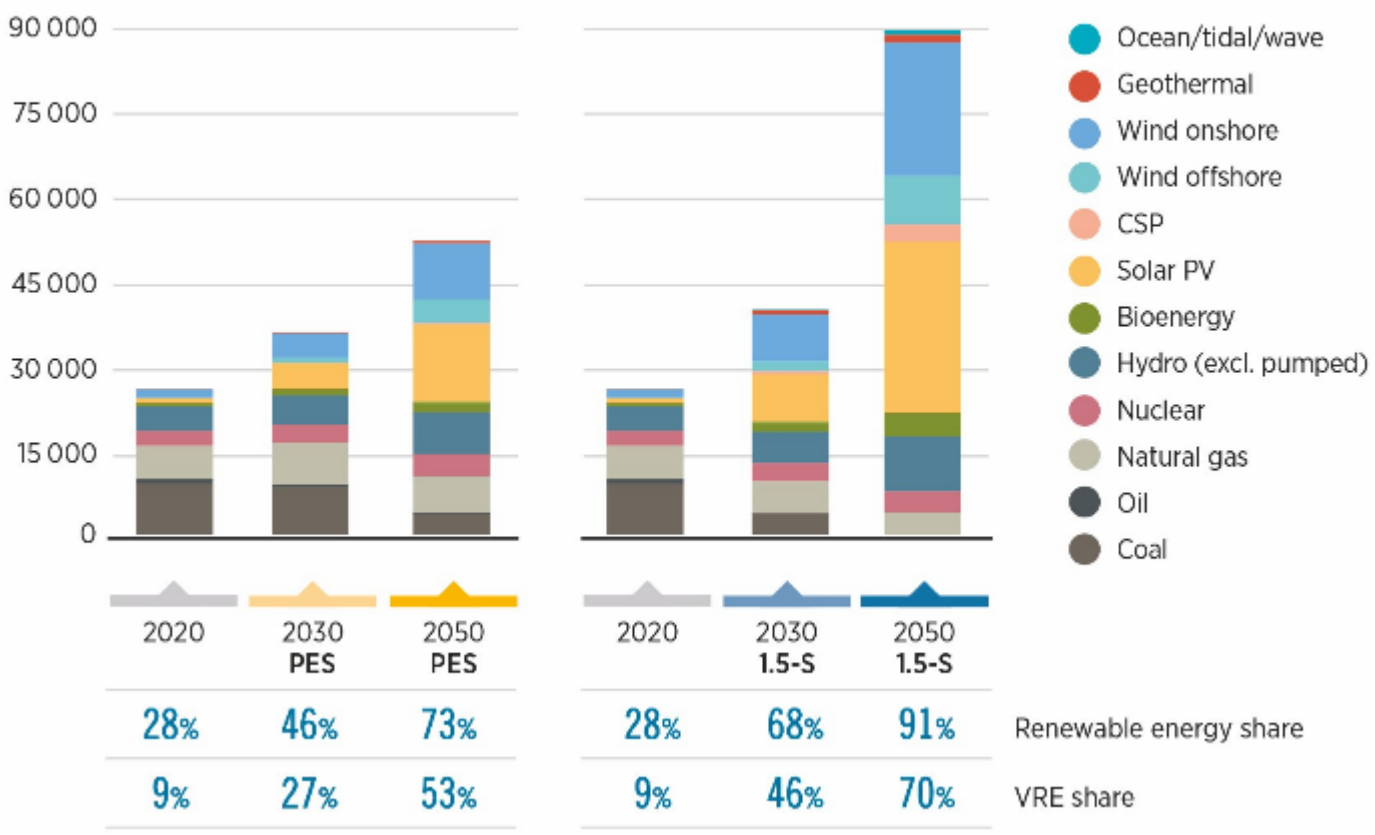
Note: GW = gigawatt

- Largest ever annual increase in renewable energy additions reported in 2022 (295GW)
- Expansion of renewable power generation in 2022 confirms upward trend of renewables against declining new fossil fuel capacity.
- Large-scale deployment remains centred on a limited number of counties and regions, it is essential to expand deployment in nations that lack access to electricity.

Source: IRENA WETO 2023

IRENA Projection: Renewables will dominate the power generation mix

FIGURE 2.3 **Global power generation mix and installed capacity by energy source: Planned Energy Scenario and 1.5°C Scenario in 2020, 2030 and 2050**



Notes: 1.5-S = 1.5° C Scenario; CSP = concentrated solar power; GW = gigawatt; PES = Planned Energy Scenario; PV = photovoltaic; VRE = variable renewable energy; TWh = terawatt hour. Bioenergy includes biogas, biomass waste, biomass solid, and biomass solid CCS; CCS = carbon capture and storage.

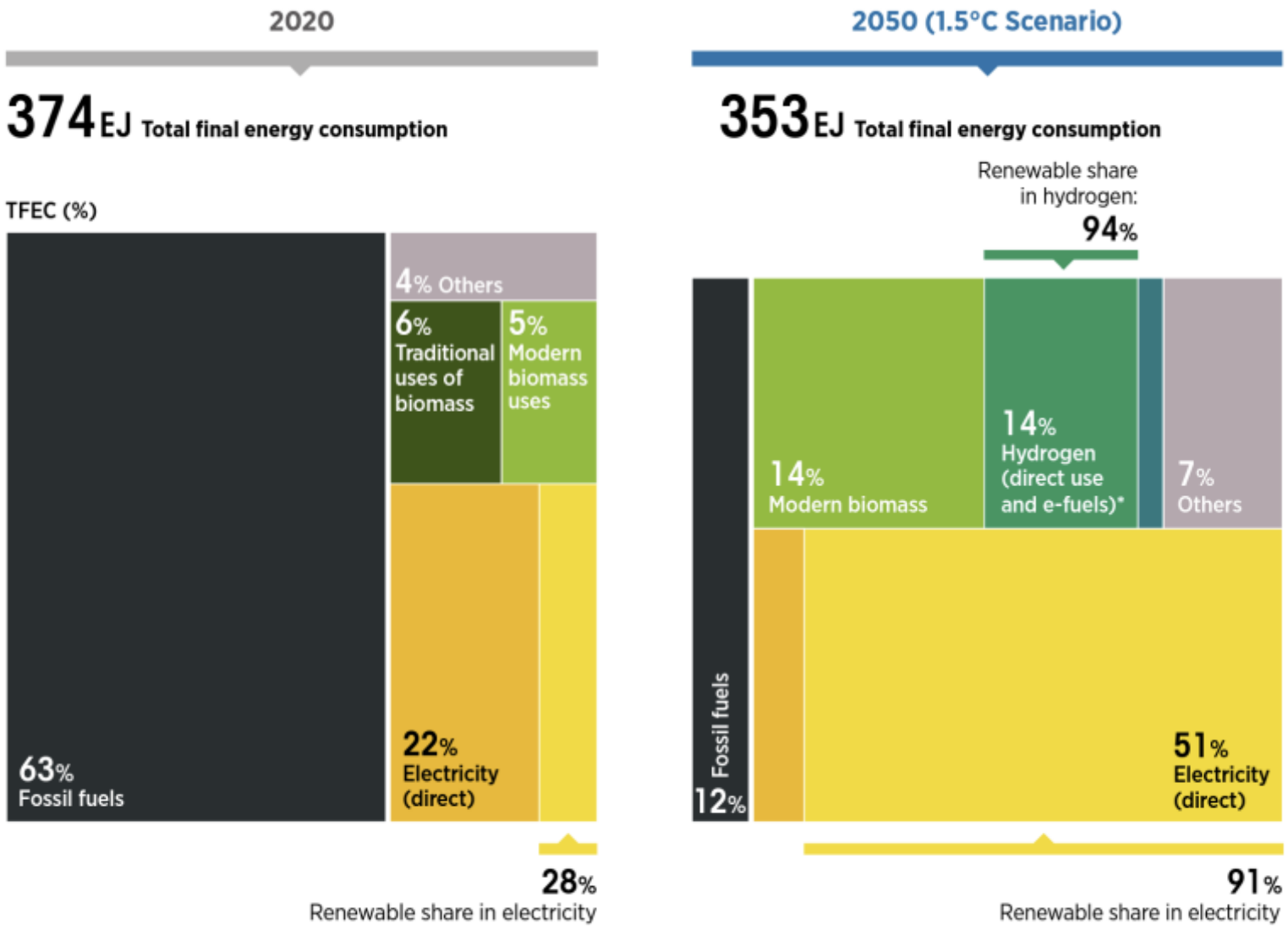
- Under 1.5°C Scenario, end-use sectors would see rapid electrification by 2050, causing global electricity demand (including for green hydrogen production) to triple from 2020 level and reach over 75 000 TWh.
- Power sector undergoes deeper decarbonisation than most other sectors, reaching **68%** and **91%** of RE share in total electricity generation in 2030 and 2050.
- **Variable renewable energy** (solar PV and wind) would dominate the transformation of the global electricity sector and account for **70% of electricity generation in 2050**.

Source: IRENA WETO 2023

Smart Electrification within power system and end use sectors are essential

- **Energy transition is driven by:**
  - Climate targets: Decarbonisation of energy sectors
  - Security of energy supply and affordability: decrease dependency of imported fossil fuels

90% of total electricity needs will be supplied by renewables by 2050

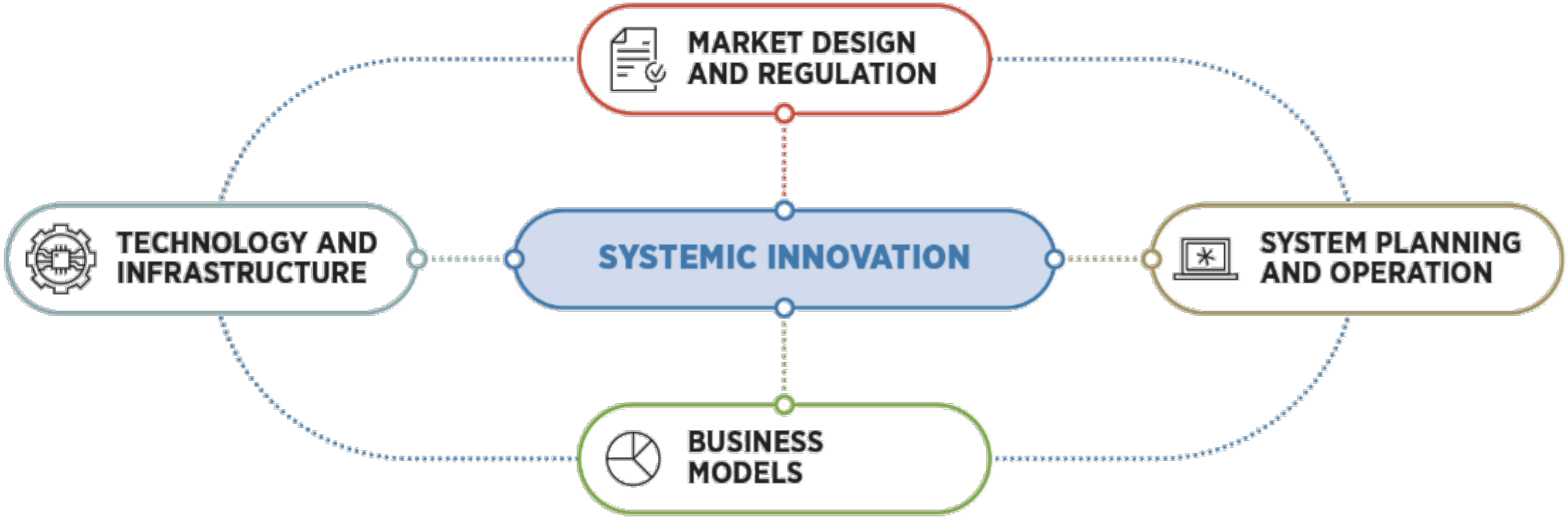


Source: IRENA Innovation Landscape Report 2023

Source: (IRENA, 2023c).

A smart approach requires systemic innovation

It is only by matching and leveraging synergies in innovations in all parts of the power system and end-use sectors and including all relevant actors and stakeholders that successful solutions can be implemented on the ground.



Source: IRENA Innovation Landscape Report 2023

Power to mobility: 35 innovations

Source: IRENA Innovation Landscape Report 2023

Dimension	Category	Innovation	Innovation readiness level	Impact on electrification of end uses	Smart electrification
TECHNOLOGY AND INFRASTRUCTURE	ELECTRIC VEHICLE	1 EV model evolution	●●●○	●●●●	●●○○
		2 EV batteries	●●●○	●●●●	●●●○
		3 Battery recycling technology	●●○○	●○○○	●○○○
	CHARGING INFRASTRUCTURE	4 Diversity and ubiquity of charging points	●●●○	●●●●	●●○○
		5 Wireless charging	●○○○	●●●○	●●○○
		6 Overhead charging	●●●●	●●●○	●●○○
		7 Portable charging stations	●●○○	●●●○	●●○○
		8 V2G systems	●●○○	●●○○	●●●●
	DIGITALISATION	9 Digitalisation for energy management and smart charging	●●○○	●●○○	●●○○
		10 Blockchain-enabled transactions	●●○○	●○○○	●○○○
	POWER SYSTEM ENABLERS	11 Smart distribution transformers	●●●○	●●○○	●●●●
		12 Smart meters and submeters	●●●●	●○○○	●●●○
MARKET DESIGN AND REGULATION	ELECTRICITY MARKET DESIGN	13 Dynamic tariffs	●●○○	●●○○	●●●●
		14 Smart charging for local flexibility	●○○○	●○○○	●●●●
		15 Smart charging for system flexibility	●●○○	●○○○	●●●●
	REGULATION FOR CHARGING INFRASTRUCTURE	16 "Right to plug" regulation	●●○○	●●●●	●○○○
		17 Streamlining permitting procedures for charging infrastructure	●●○○	●●●●	●○○○
		18. Standardisation and interoperability	●●●○	●●●●	●●●●
		19 V2G grid connection code	●●○○	●○○○	●●●●
SYSTEM PLANNING AND OPERATION	STRATEGIC PLANNING	20 Cross-sectoral co-operation and integrated planning	●●○○	●●○○	●●●●
		21 Including EV load in power system planning	●●○○	●●●○	●●●●
		22 Grid data transparency	●●○○	●○○○	●●●●
		23 Clean highway corridors	●○○○	●●●●	●●○○
	SMART OPERATION	24 Operational flexibility in power systems to integrate EVs	●●○○	●●●○	●○○○
		25 Management of flexible EV load to integrate variable renewable energy	●●○○	●●●●	●●●●
		26 Management of flexible EV load to defer grid upgrades	●●○○	●●○○	●●●●
		27 EV as a resilience solution	●●○○	●○○○	●●●○
BUSINESS MODELS	SERVICES FOR THE POWER SYSTEM	28 EV aggregators	●●●○	●○○○	●●●●
		29 Shaving of EV peak loads using DERs	●●●○	●○○○	●●●●
		30 Battery second life	●●○○	●●○○	●○○○
	SERVICES FOR THE TRANSPORT SECTOR	31 EV charging as a service	●●●○	●●●○	
		32 E-mobility as a service	●●●●	●●●○	●○○○
	MODELS TO ENABLE DEPLOYMENT	33 Ownership and operation of public charging stations	●●●○	●●●●	●○○○
		34 A single bill for EV charging at home and on the go	●●○○	●●●○	●●○○
		35 Battery swapping	●●○○	●●●○	●●●○

●●●● Very high ●●●○ High ●●○○ Medium ●○○○ Low

Power to Heat: 35 innovations

Source: IRENA Innovation Landscape Report 2023

Dimension	Category	Innovation	Innovation readiness level	Impact on electrification of end uses	Smart electrification
TECHNOLOGY AND INFRASTRUCTURE	CONVERSION TECHNOLOGIES	1 Low-temperature heat pumps	●●●●	●●●●	●●○○
		2 Hybrid heat pumps	●●●●	●●●●	●●○○
		3 High-temperature heat pumps	●○○○	●●●●	●●○○
		4 Waste heat-to-power technologies	●●●●	●○○○	●●○○
		5 High-temperature electricity-based applications for industry	●○○○	●●●○	●○○○
	THERMAL ENERGY STORAGE	6 Low-temperature thermal energy storage	●●●○	●●○○	●●●●
		7 Medium- and high-temperature thermal energy storage	●●○○	●●○○	●●●●
	DISTRICT HEATING AND COOLING SYSTEMS	8 Fourth-generation district heating and cooling systems	●●●○	●●○○	●●●●
		9 Fifth-generation district heating and cooling systems	●○○○	●○○○	●●●●
	DIGITALISATION	10 Internet of Things for smart electrification	●●●○	●○○○	●●●●
		11 Artificial intelligence for forecasting heating and cooling demands	●●●○	●●○○	●●●●
		12 Blockchain for enabling transactions	●●○○	●○○○	●●○○
		13 Digitalisation as a flexibility enabler	●●○○	●●○○	●●●●
MARKET DESIGN AND REGULATION	ELECTRICITY MARKET DESIGN	14 Dynamic tariffs	●●●○	●●○○	●●●●
		15 Flexibility through thermal loads	●●●○	●●○○	●●●●
		16 Flexible power purchase agreement	●●○○	●●○○	●●●○
	END-USE SECTOR REGULATION AND INCENTIVES	17 Standards and certifications for improved predictability of heat pump operation	●●●○	●●●○	●○○○
		18 Energy efficiency programmes for buildings and industries	●●●●	●●○○	●●●○
MARKET DESIGN AND REGULATION	END-USE SECTOR REGULATION AND INCENTIVES	19 Building codes for power-to-heat/cooling solutions	●○○○	●●●○	●●○○
		20 Streamlining permitting procedures for thermal infrastructures	●●○○	●●●●	●○○○
SYSTEM PLANNING AND OPERATION	INTEGRATED PLANNING	21 Holistic planning for cities	●●●○	●●●○	●●○○
		22 Heating and cooling maps	●●●○	●○○○	●●○○
		23 Coupling cooling loads with solar generation	●●●●	●●○○	●●●●
	SMART OPERATION	24 Smart operation with thermal inertia	●●○○	●○○○	●●●●
		25 Smart operation with seasonal thermal storage	●●○○	●○○○	●●●●
		26 Smart operation of industrial heating	●●●○	●●○○	●●●●
		27 Combining heating and cooling demand in district systems	●●○○	●○○○	●●○○
BUSINESS MODELS	SERVICES FOR THE ENERGY SYSTEM	28 Aggregators	●●●●	●○○○	●●●●
		29 Distributed energy resources for heating and cooling demand	●●●●	●●○○	●●●●
		30 Heating and cooling as a service	●●●○	●●○○	●●●○
	WASTE HEAT RECOVERY MODELS	31 Waste heat recovery from data centres	●●●●	●●○○	●●●●
		32 Eco-industrial parks and waste heat recovery from industrial processes	●●●○	●○○○	●●○○
		33 Circular energy flows in cities – booster heat pumps	●●●●	●○○○	●●●○
	ENERGY COMMUNITIES	34 Community-owned district heating and cooling	●●●○	●○○○	●●○○
		35 Community-owned power-to-heat assets	●●○○	●●○○	●●●●

●●●● Very high ●●●○ High ●●○○ Medium ●○○○ Low

Power to Hydrogen: 30 innovations

Source: IRENA Innovation Landscape Report 2023

Dimension	category	Innovation	Innovation readiness level	Impact on electrification of end uses	Smart electrification
TECHNOLOGY AND INFRASTRUCTURE	ELECTROLYSER TECHNOLOGY	1 Pressurised alkaline electrolysers	●●○○	●●●●	●●●○
		2 Polymer electrolyte membrane electrolysers	●●○○	●●●●	●●●○
		3 Solid oxide electrolyser cells electrolysers	●○○○	●●●●	●○○○
		4 Anion exchange membrane electrolyser	●○○○	●●●●	●●●○
	HYDROGEN INFRASTRUCTURE	5 Compressed hydrogen storage	●●●○	●●●○	●●●●
		6 Liquefied hydrogen storage	●●○○	●●●○	●●●●
		7 Hydrogen-ready equipment	●●●○	●●●○	●○○○
	DIGITAL TECHNOLOGIES	8 Digital backbone for green hydrogen production	●●●○	●○○○	●●●●
		9 Hydrogen leakage detection	●○○○	●●●●	●○○○
MARKET DESIGN AND REGULATION	ELECTRICITY MARKET DESIGN	10 Additionality principle	●○○○	●○○○	●●●●
		11 Renewable power purchase agreement for green hydrogen	●●●○	●○○○	●●●○
		12 Cost-reflective electricity tariffs	●●●○	●○○○	●●○○
		13 Electrolysers as grid service providers	●●○○	●○○○	●●●●
	HYDROGEN MARKET	14 Certificates	●●○○	●●●○	●●●○
		15 Hydrogen purchase agreement scheme	●○○○	●●●●	●●○○
		16 Carbon contract for difference	●○○○	●●●●	●●○○
	STANDARDS AND REGULATION	17 Regulatory framework for a hydrogen network	●○○○	●●●●	●○○○
		18 Streamlining permitting for hydrogen projects	●●○○	●●●●	●○○○
		19 Quality infrastructure for green hydrogen	●○○○	●●●●	●●●○
		20 Regulatory sandboxes	●●●○	●●●●	●●●○
SYSTEM PLANNING AND OPERATION	STRATEGIC PLANNING	21 Electricity transmission system operators including hydrogen facilities in their planning	●○○○	●●○○	●●●●
		22 Co-locating electrolysers with renewable generators (onshore and offshore)	●●○○	●●●○	●●●○
	SMART OPERATION	23 Smart hydrogen storage operation and power-to-power routes	●○○○	●○○○	●●●●
		24 Long-term hydrogen storage	●○○○	●○○○	●●●●
		25 Co-operation between electricity and gas operators	●○○○	●●○○	●●●○
BUSINESS MODELS	PRIMARY REVENUE STREAM	26 Local hydrogen demand	●●○○	●●●○	●○○○
		27 Hydrogen trade	●○○○	●●●●	●○○○
		28 Hydrogen industrial hub	●○○○	●●●○	●●○○
	STACKING OTHER REVENUE STREAMS	29 Revenues from flexibility provided to the power system	●○○○	●○○○	●●●○
		30 Sale of electrolysis by-products (oxygen and heat)	●●○○	●●○○	●○○○

●●●● Very high ●●●○ High ●●○○ Medium ●○○○ Low

Summary Smart Electrification Innovations

The bulk of the energy transition relies on **renewable electricity as main energy carrier** of the future

Two main challenges addressed with this analysis:

- How to **accelerate the energy transition** through innovation
- How to electrify end-use energy demand while **minimising infrastructure costs and optimising power systems**

Smart electrification creates a virtuous circle where **end-use sectors –mobility, industry and buildings- are decarbonise while the new loads become flexibility options** for the system

- Cost difference between uncontrolled and smart electrification is around one order of magnitude – globally from 1 USD trillion per year vs more than 10 USD trillion per year

Innovation for smart electrification is needed in four dimenssions **technology, business models, regulation and systems operation**

IRENA developed an **innovation toolbox with 100 innovations** that countries can tailor to their context for successful smart electrification of **Mobility, Heat & Cooling and Green Hydrogen** energy demand

Access here:
Innovation Landscape for Smart Electrification Decarbonising end-use sectors with renewable power

Access here:
World Energy Transitions Outlook 2023: 1.5°C Pathway

THANK YOU!

IRENA
International Renewable Energy Agency