



TECHNICAL SESSION 2 · DAY 1 · 14:30–15:00

Regional Energy Architecture & Technology Fundamentals of Renewable Energy in SAARC

Solar PV · Wind · Small Hydro · Bioenergy & WtE · Solar Thermal · Geothermal · Green Hydrogen — the physics that drives project economics

Dr. Irfan Yousuf

Energy Policy · Tariff · Private Investment · Climate Finance & Carbon Markets

Hotel Galle Face, Colombo · 5–7 October 2026



SAARC Training Workshop on Financial Modeling for Renewable Energy Projects

Map for illustration only; not an authoritative depiction of boundaries.



SESSION 2 · LEARNING OBJECTIVES

What you will be able to do after this session

- 1 Explain how SAARC's eight power systems and cross-border links shape RE investment
- 2 Describe how solar, wind, small hydro, bioenergy, WtE, solar thermal and geothermal convert resource into kWh
- 3 Identify the physical parameters that enter a tariff model for each technology
- 4 Distinguish variable from dispatchable RE — and why fuel-based options need an Energy Purchase Price
- 5 Relate green hydrogen economics to the cost and utilisation of RE power
- 6 Rank which parameters move the tariff most, using our workshop model



WHY TECHNOLOGY MATTERS TO FINANCE

One equation sits behind every RE tariff

$$\text{Tariff} \approx \text{Capex} \times \text{CRF} + \text{Fixed O\&M} \div \text{MW} \times 8,760 \times \text{CUF} + \text{VOM}$$

CRF = capital recovery factor (cost of capital, tenor) · CUF = capacity utilisation factor (resource, losses) ·
VOM = variable O&M



Capex

USD/kW: equipment,
BoS, grid, development



Cost of capital

Debt rate, equity return,
tenor



Capacity factor

Resource quality × plant
losses



O&M

Fixed USD/kW-yr,
variable USD/MWh

QUICK POLL 🙋 Which lever moves your tariff most? A Capex · B Cost of capital · C Capacity factor · D O&M



GLOBAL LANDSCAPE

2025: another record year for renewable capacity

5,149 GW

Global renewable capacity, end-2025

692 GW

Added in 2025 (+15.5%)
— a record

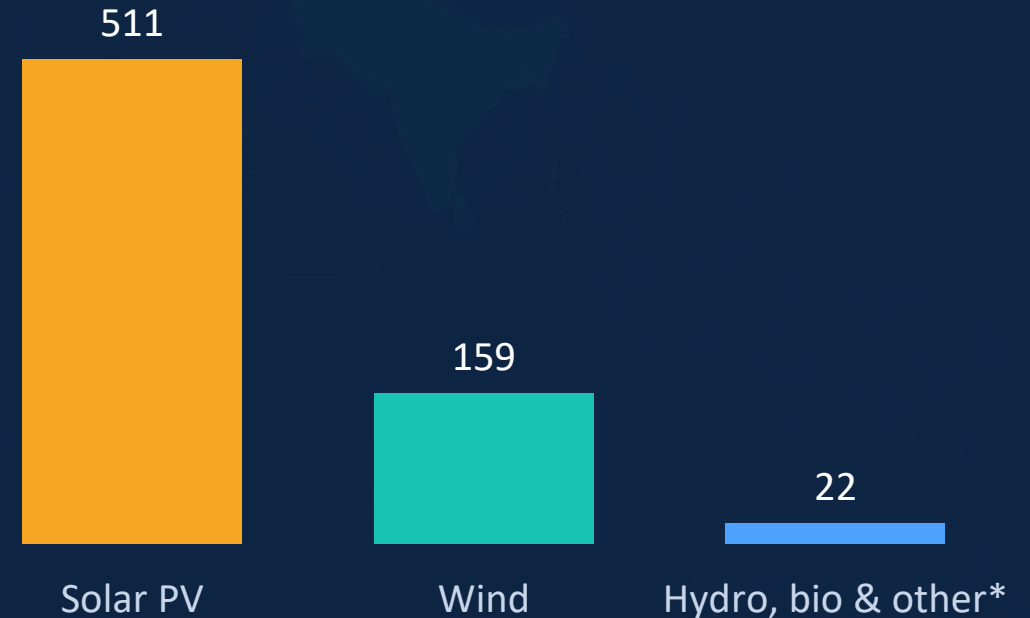
85.6%

Renewables' share of all new power capacity

74.2%

Share of 2025 additions built in Asia

Capacity added in 2025 (GW)



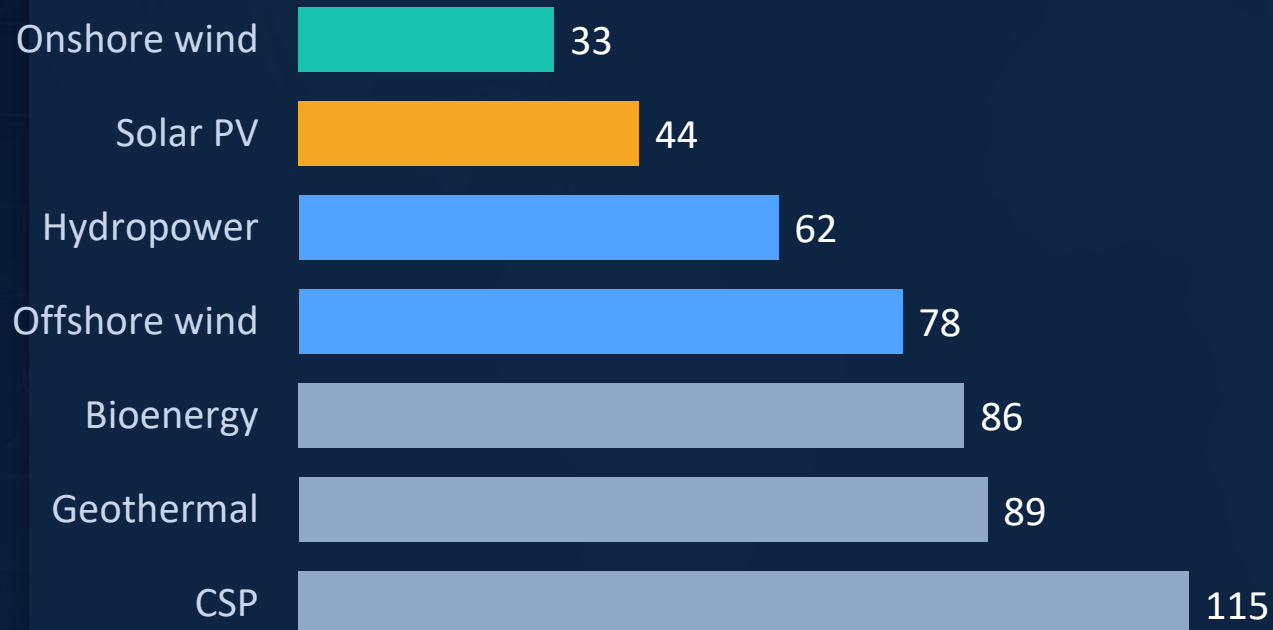
Source: IRENA, Renewable Capacity Statistics 2026 (Mar 2026). *Other = 692 – 511 – 159 GW (derived).



GLOBAL COST BENCHMARKS

Renewables are now the cheapest source of new power

Global weighted-average LCOE, 2025 (USD/MWh)



-90%

Solar PV LCOE, 2010→2024: USD 0.417 → 0.043/kWh

USD 691 / 1,041

Installed cost per kW, 2024: solar PV / onshore wind

>90%

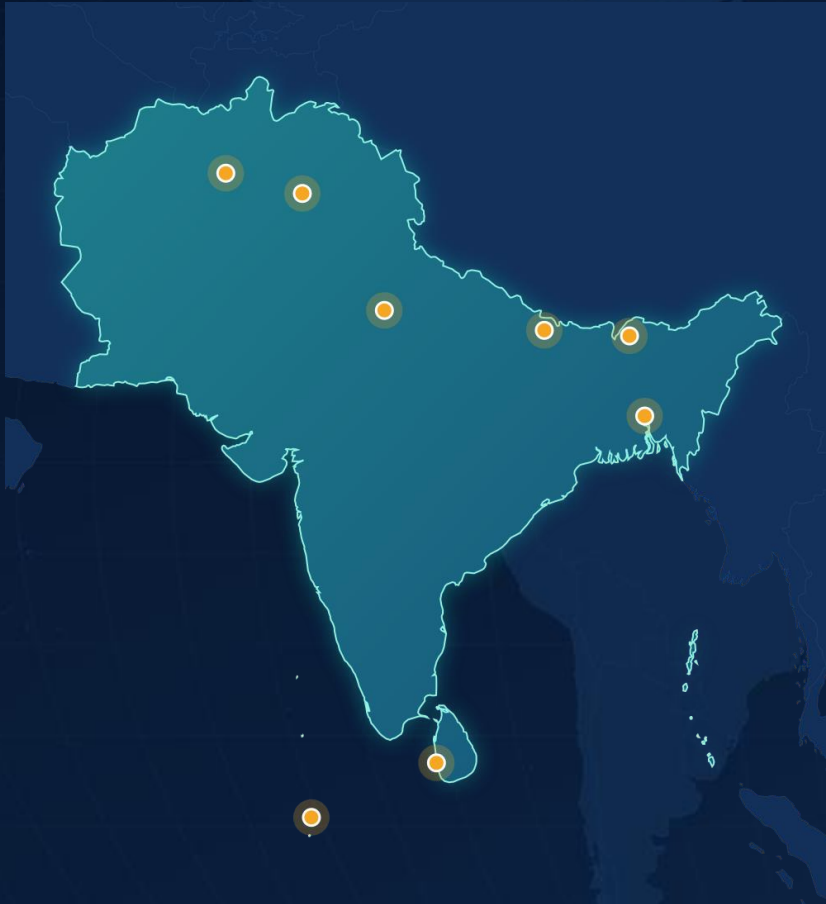
of 2025 utility-scale RE cheaper than lowest-cost new fossil

Source: IRENA, Renewable Power Generation Costs in 2025 (Jul 2026) and in 2024 (Jul 2025).



REGIONAL SNAPSHOT

SAARC at a glance: eight power systems, one region



Afghanistan

65% of total capacity, mainly hydro (58%) & solar (7%)



Bangladesh

20% RE by 2030 · 30% by 2040



Bhutan

Hydro exporter · 1 GW solar goal 2030



India

291.7 GW RE · 500 GW non-fossil 2030



Maldives

5.8% RE mainly solar, 33% by 2028



Nepal

Hydro-led · 1.05 GW export capacity



Pakistan

38 GW distributed solar and 2.6 MW IPP wind solar (FY25)



Sri Lanka

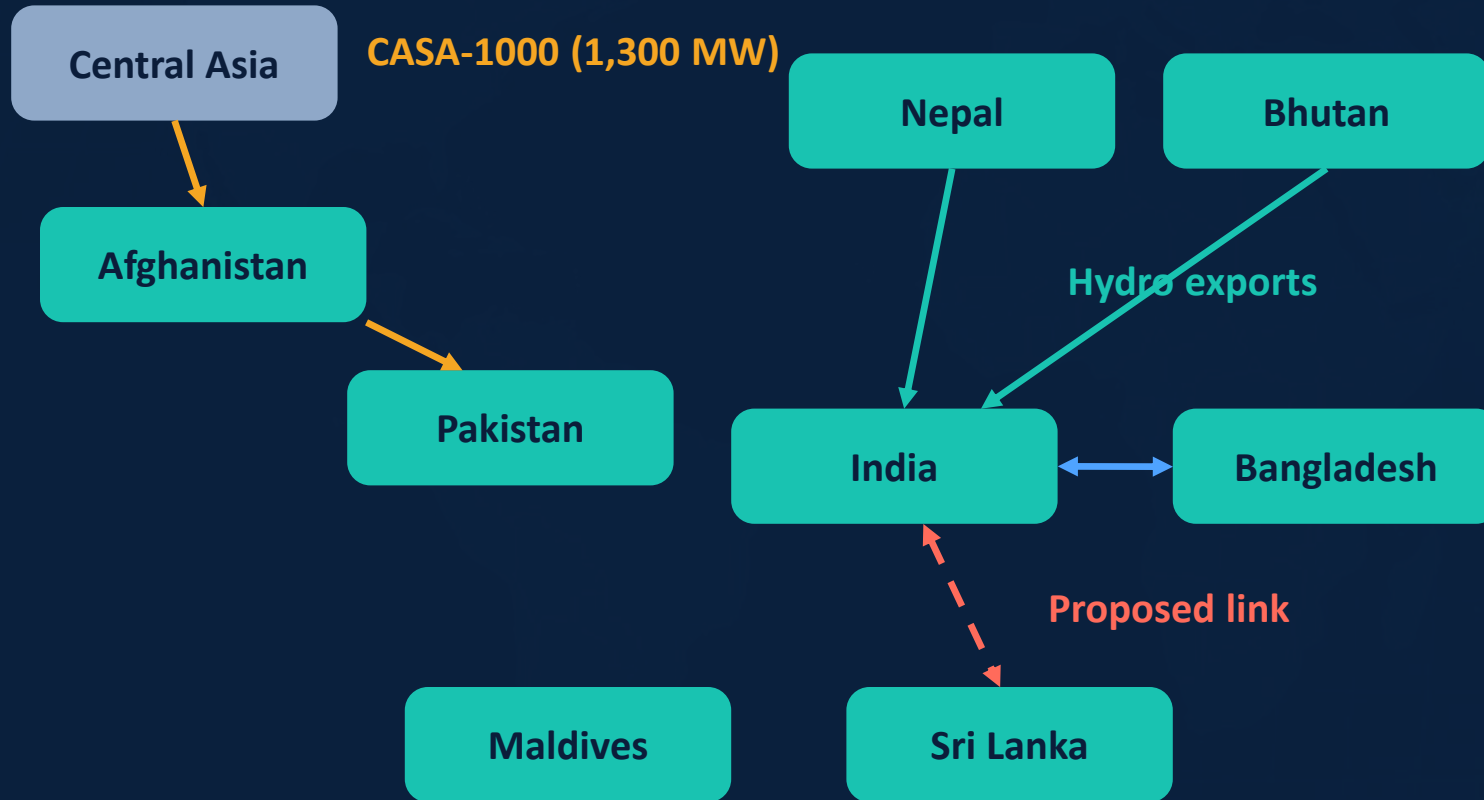
70% RE electricity by 2030

Source: MNRE (Jul 2026); Ember/Renewables First (2026); SREDA/BSS (2025); PUCSL (2026); SASEC; Yog Infra Q3-2025.



ARCHITECTURE

Regional energy architecture: from national grids to cross-border trade



Why it matters for tariffs

- Bigger markets → larger, cheaper projects
- Cross-border PPAs need bankable, transparent tariffs
- Hydro + solar + wind complement seasonally
- SAARC Framework Agreement for Energy Cooperation (Electricity), 2014



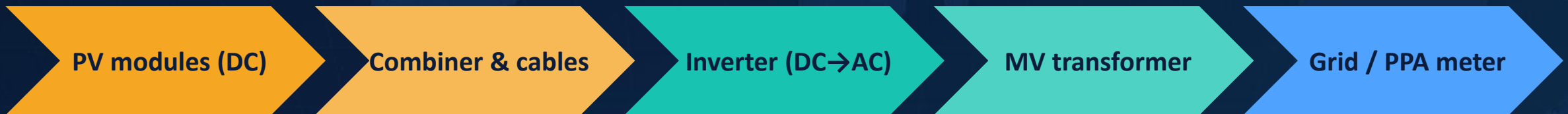
TECHNOLOGY FUNDAMENTALS · 1

Solar PV: configuration and the parameters that set yield



What drives energy yield

- Resource: global horizontal irradiation (kWh/m²/day)
- Mounting: fixed-tilt vs single-axis tracker
- DC/AC ratio, module temperature, soiling
- Module degradation (≈0.4%/yr in model)
- Global average CUF of new PV: 17.4% (2024)



Source: IRENA, Renewable Power Generation Costs in 2024 (capacity factor). Degradation = workshop model default (illustrative).



TECHNOLOGY FUNDAMENTALS · 2

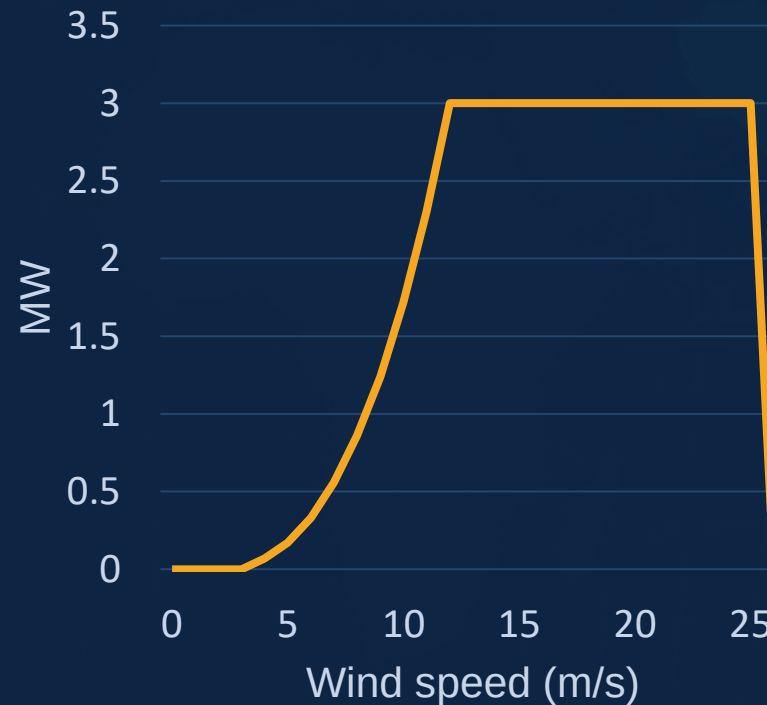
Wind: energy grows with the cube of wind speed



$$P = \frac{1}{2} \cdot \rho \cdot A \cdot C_p \cdot v^3$$

+10% wind speed $\approx$ +33% power
($1.1^3 = 1.33$), until rated speed

Illustrative 3 MW power curve



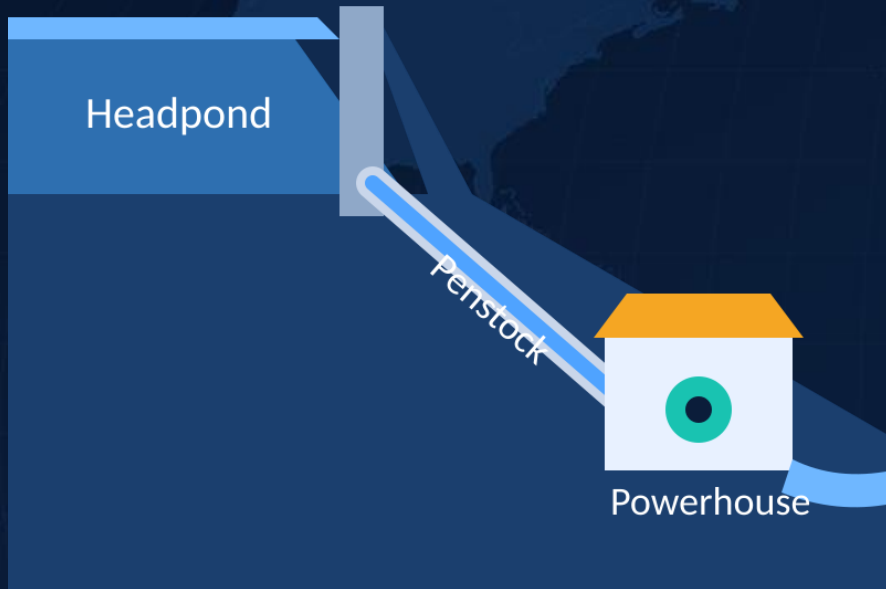
Key parameters

- Mean speed at hub height
- Weibull shape (k)
- Wind shear (α)
- Air density
- Wake & direction
- Cut-in / rated / cut-out



TECHNOLOGY FUNDAMENTALS · 3

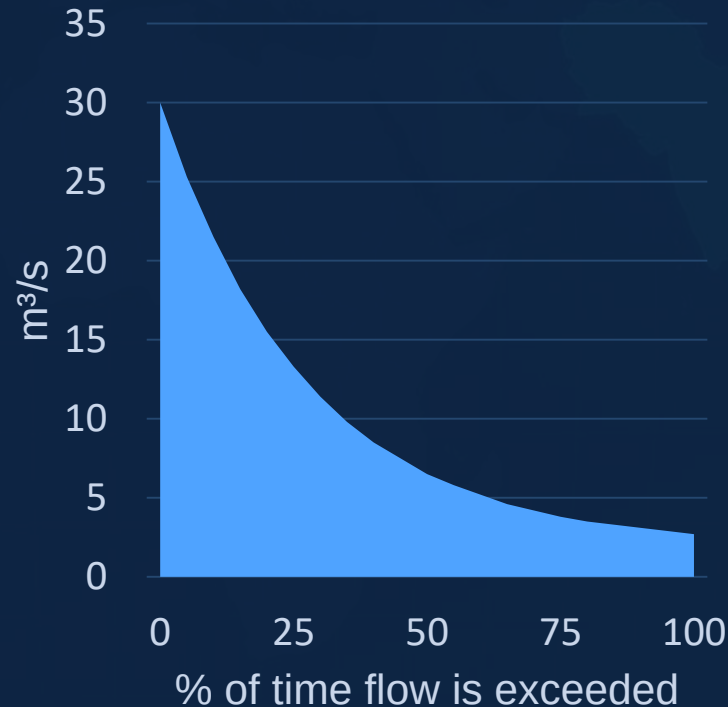
Small hydropower: head × flow, shaped by the seasons



$$P \text{ (kW)} \approx 9.81 \cdot Q \cdot H \cdot \eta$$

$$Q = 10, H = 50, \eta = 0.85 \rightarrow \approx 4.2 \text{ MW}$$

Illustrative flow-duration curve



Key parameters

- Gross & net head
- Design flow (from FDC)
- Environmental flow
- Run-of-river vs pondage
- Sediment & geology
- Dry-season output



TECHNOLOGY FUNDAMENTALS · 4

Beyond solar, wind and hydro: the wider renewable family



Biomass

Burns crop residues, bagasse or wood to raise steam. Dispatchable.

LCOE 2025: USD 86/MWh (bioenergy)



Waste-to-energy

Incinerates municipal waste; is paid a tipping fee to take it.

Case: Kerawalapitiya, Colombo (10 MW)



Biogas

Digests manure & organic waste; the gas fuels an engine.

By-products: fertiliser, carbon credits



Solar thermal

Mirrors concentrate sun → heat → turbine; storage adds dispatch.

LCOE 2025: USD 115/MWh (CSP)



Geothermal

Earth heat drives flash or binary turbines — near-baseload.

LCOE 2025: USD 89/MWh



Green hydrogen

RE power splits water; H₂ for fertiliser, refining, steel.

An RE off-taker, not a power source

Source: IRENA, Renewable Power Generation Costs in 2025 (global weighted-average LCOE).



TECHNOLOGY FUNDAMENTALS · 5

Bioenergy, waste-to-energy and biogas: the fuel is the business

Biomass

Residue collection

▼ Boiler

▼ Steam turbine

▼ Grid

- Fuel: rice husk, bagasse, cotton stalk, wood chips
- Net efficiency 20–30%
- Heat rate = $3.6 \div \text{efficiency}$ (GJ/MWh)
- Key risk: fuel price & supply chain

Waste-to-energy

Municipal waste

▼ Incinerator / grate

▼ Flue-gas cleaning

▼ Grid

- Low calorific value of wet mixed waste
- High auxiliary load & emission controls
- Revenue: tariff + tipping (gate) fee
- Key risk: waste quantity & quality

Biogas

Manure / organic waste

▼ Digester

▼ Gas engine or upgrader

▼ Grid / gas pipe

- Gas yield depends on feedstock mix
- Engine efficiency 35–40%
- By-products: digestate, carbon credits
- Key risk: feedstock logistics

Source: Efficiency ranges typical of the technologies; workshop model defaults on Tech_Library (illustrative).



TOMORROW'S FIELD VISIT

Case study: Kerawalapitiya waste-to-energy plant, Sri Lanka

10 MW

Grid-connected capacity

600–800

Tonnes of municipal waste per day

LKR 15 bn

Total investment

20 years

Waste supply + power purchase agreements

Colombo Municipal Council
Supplies waste under a 20-yr Waste Supply Agreement

Western Power Company (Aitken Spence)
Builds, owns and operates the plant

Ceylon Electricity Board
Buys power under a 20-yr Standardised PPA

Debt: LKR 9 bn syndicated loan led by HNB with Bank of Ceylon, DFCC and People's Bank · Watch on site: waste reception, grate, flue-gas cleaning, ash reuse

Source: Aitken Spence (Feb 2021); Daily FT (Feb 2021); Daily News (Jun 2018); UN Global Compact.



TECHNOLOGY FUNDAMENTALS · 6

Solar thermal and geothermal: dispatchable heat-to-power



Solar thermal (CSP & solar heat)

- Parabolic trough, tower or linear Fresnel concentrate direct sunlight (DNI)
- Molten-salt storage shifts output into the evening peak
- Same collectors supply industrial process heat and water heating
- Needs high direct irradiation; heavy capex; long build

Global LCOE 2025: USD 115/MWh



Geothermal

- Flash plants (high-temperature) or binary cycles (moderate temperature)
- Runs 85–90% of the time — near-baseload
- Exploration drilling is the key, front-loaded risk
- Reservoir output declines unless make-up wells are drilled

Global LCOE 2025: USD 89/MWh

Source: IRENA, Renewable Power Generation Costs in 2025. Capacity-factor range typical of geothermal plants.



TECHNOLOGY FUNDAMENTALS · 7

Green hydrogen: a new, large buyer of renewable electricity



$$\text{LCOH} \approx \text{capex} \times \text{CRF} \div \text{kg/yr} + \text{kWh/kg} \times \text{electricity price} + \text{O\&M}$$

From our workshop model

Electrolyser fed by the 50 MW solar plant (CUF 19.5%, power at 59 USD/MWh):

$$\text{LCOH} \approx \text{USD } 11.6/\text{kg}$$

Low utilisation, not the power price, drives cost — with geothermal-level utilisation it falls to $\approx$ USD 8.8/kg.

India's National Green Hydrogen Mission targets 5 Mt/yr by 2030.

\$1.5–2.4k/kW

Electrolyser installed cost (Chinese units abroad)

50,000 h

Economic stack life assumed by IEA

\$2–9/kg

Renewable H2 by 2030 (IEA NZE)

Source: IEA, Global Hydrogen Review 2025 & 2024; MNRE (NGHM); workshop model H2_LCOH sheet (illustrative).



WHAT ENTERS THE MODEL · 1

Variable RE: three technologies side by side

Parameter	Solar PV	Wind	Small hydro
Resource metric	Irradiation (kWh/m ²)	Wind speed at hub (m/s)	Head (m) × flow (m ³ /s)
Typical CUF range	16–22%	25–40%	40–60%
Construction period	6–12 months	12–18 months	24–36 months
Installed cost (global, 2024)	USD 691/kW	USD 1,041/kW	Highly site-specific
Main yield risk	Soiling, heat, degradation	Wake, shear, turbine availability	Hydrology, sediment
Energy uncertainty (σ , model)	≈6%	≈12%	≈10%
Model default (Tech_Library)	700 USD/kW · 21% gross CF	1,100 USD/kW · 33%	2,500 USD/kW · 50%

Source: IRENA RPGC 2024 (installed costs). Ranges and σ = typical values / workshop defaults — replace with national data.



WHAT ENTERS THE MODEL · 2

Dispatchable and emerging options: what enters the model

Parameter (model default)	Biomass	Waste-to-energy	Biogas	Geothermal	Solar thermal
Gross availability / CF	85%	85%	85%	88%	50% (with storage)
Net efficiency	25%	20%	38%	—	—
Fuel / feedstock	USD 3.0/GJ	USD 25-35/t	USD 2.0/GJ	—	—
Tipping fee credit	—	USD 15/t	—	—	—
Auxiliary / parasitic load	10%	15%	8%	7%	8%
Capex (USD/kW)	2,000	7,500	3,500	4,500	4,300
Main extra risk	Fuel supply & price	Waste volume, gate-fee payment	Feedstock logistics	Exploration drilling	Construction complexity

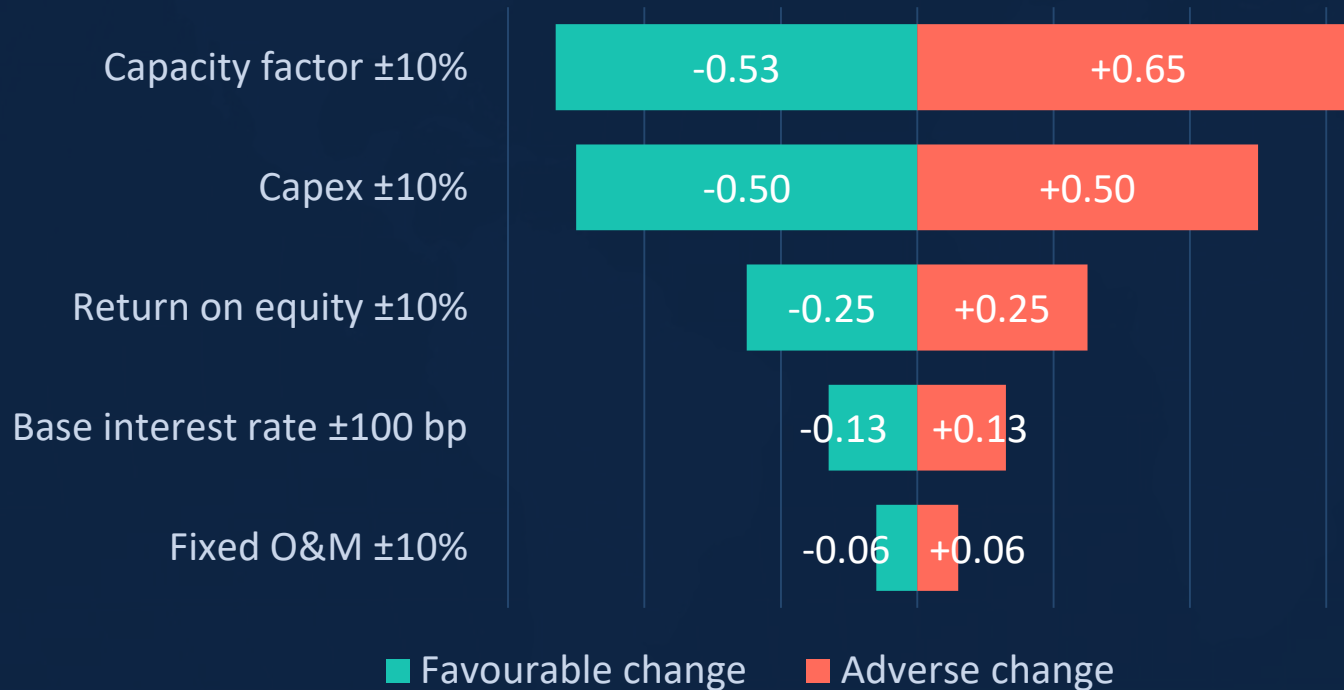
Source: Workshop model Tech_Library — illustrative defaults; WtE capex benchmarked to Kerawalapitiya (~LKR 15 bn / 10 MW).



SENSITIVITY FROM OUR WORKSHOP MODEL

Poll answer: resource and capex dominate the tariff

Change in levelised tariff vs base 5.88 US¢/kWh



5.88 ¢

Base levelised tariff — 50 MW solar, illustrative inputs

Lesson

Get the resource and the capital cost right before arguing over O&M. Financing terms come a close third.

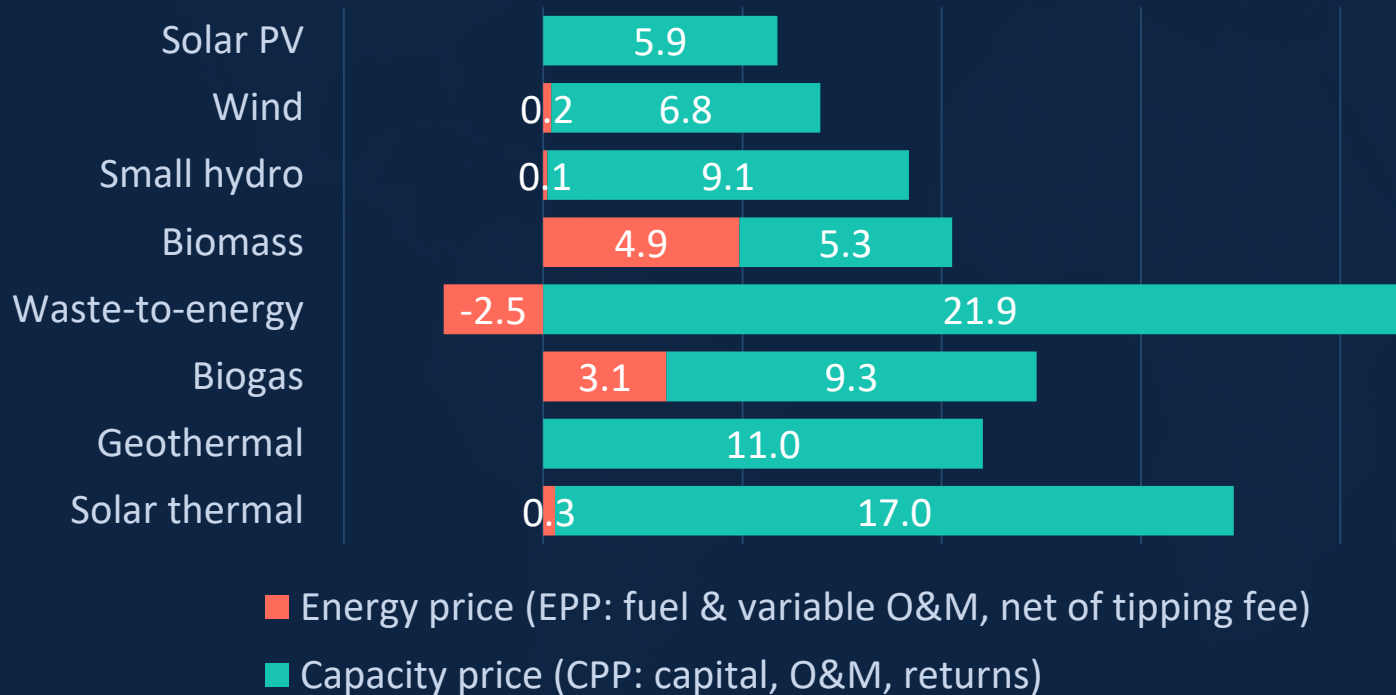
Source: Workshop tariff model (SEC_RE_Tariff_Model), default Solar PV inputs; computed by the facilitator.



MODEL PREVIEW

Same model, eight technologies — very different tariff structures

Levelised tariff, US¢/kWh — 50 MW each, default inputs



Wind: P90 DSCR $1.21\times$
 $< 1.30\times \rightarrow$ gearing must
fall to $\sim 70\%$



Biomass: 48% of the
tariff is fuel — index it
to a fuel price



WtE: tipping fee cuts
2.5 ¢, yet capex keeps it
the costliest

Source: Workshop tariff model, illustrative Tech_Library defaults — not country benchmarks.



INTERACTIVE

Quick quiz — work it out with your neighbour

Q1

A 50 MW solar plant delivers 85 GWh a year. What is its CUF?

$$85,000 \div (50 \times 8,760) = 19.4\%$$

Q2

Mean wind speed rises by 10%. Roughly how much more energy?

$$\approx +33\% (1.1^3), \text{ below rated speed}$$

Q3

$Q = 10 \text{ m}^3/\text{s}$, $H = 50 \text{ m}$, $\eta = 0.85$. Plant capacity?

$$9.81 \times 10 \times 50 \times 0.85 \approx 4.2 \text{ MW}$$



SESSION 2

Key takeaways



Equipment is cheap everywhere; resource quality and financing now decide who gets the lowest tariff.



Each technology maps to a few physical inputs — CUF, losses, efficiency, fuel, uncertainty — that go straight into the model.



SAARC's systems differ, but cross-border trade rewards transparent, comparable tariff methods.



Test before you argue: a $\pm 10\%$ error in capacity factor moves the tariff more than any O&M debate.

NEXT ► Session 3 (16:15): who pays for all this — types and sources of finance, and the risks they carry.