Australian National University

Energy in Vietnam

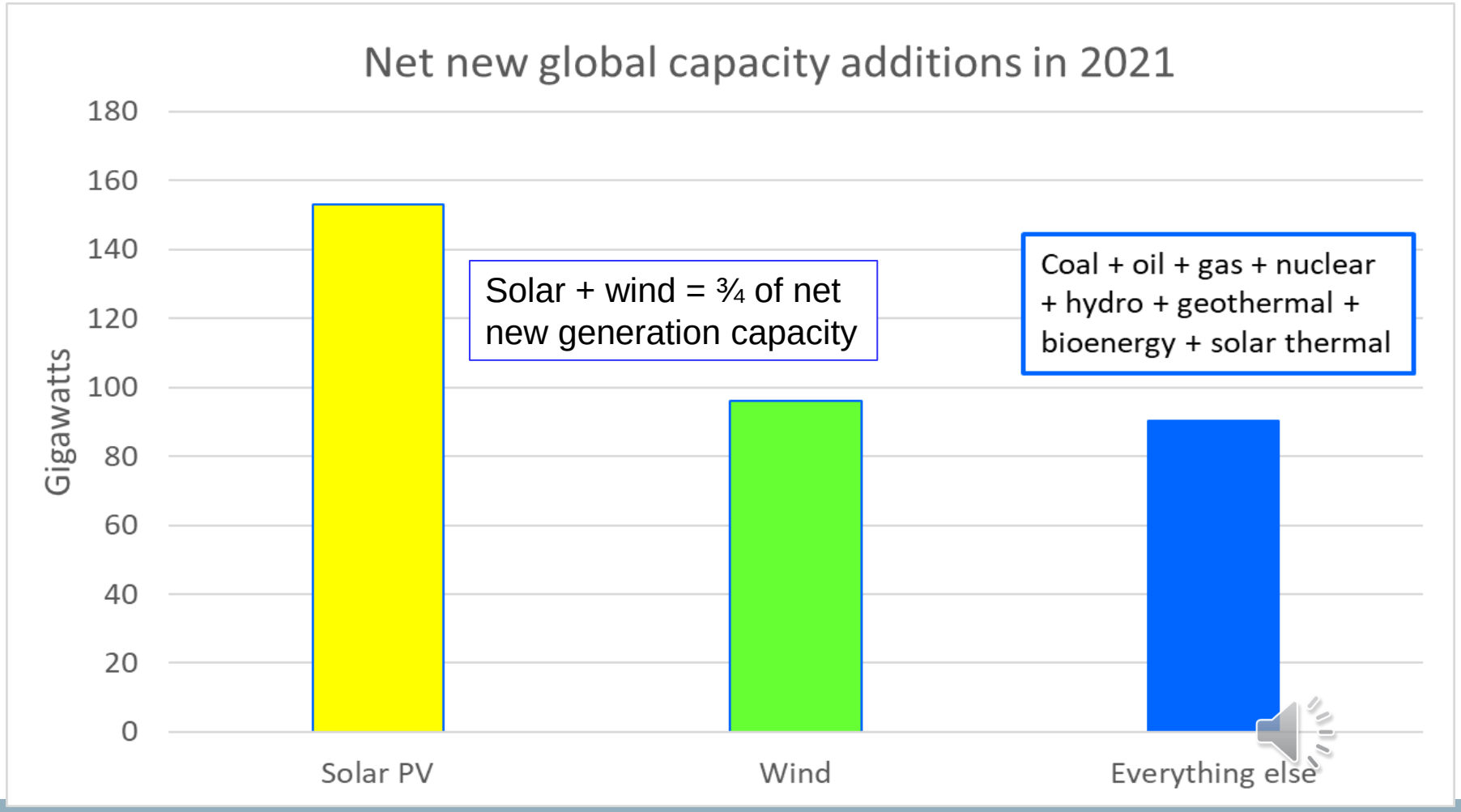
Andrew Blakers

Australian National University

http://re100.eng.anu.edu.au/

Australian National University

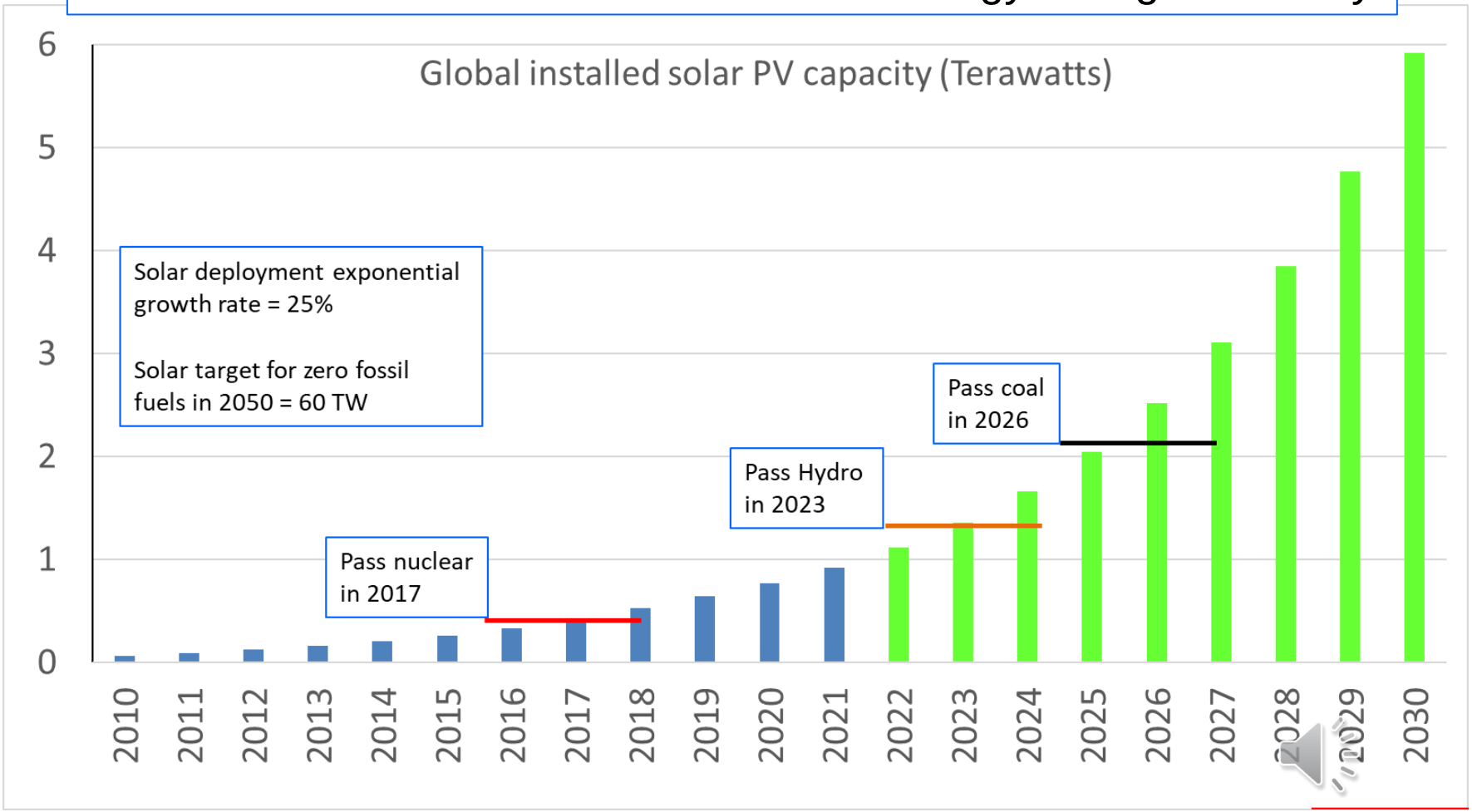
The market has spoken: solar & wind **decisively** won the energy race



Australian National University

The power of sustained exponential growth

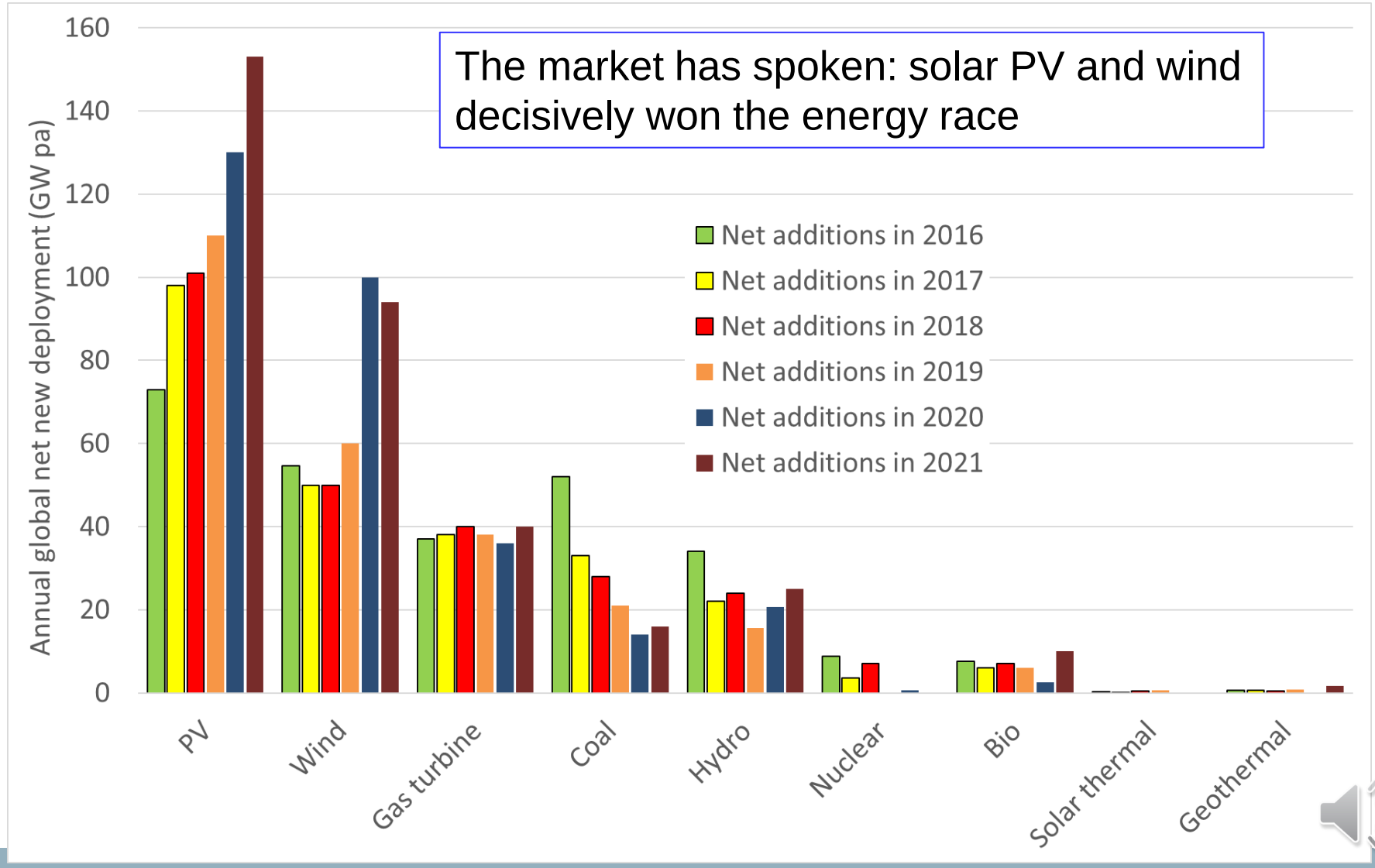
The solar & wind revolution is the fastest energy change in history



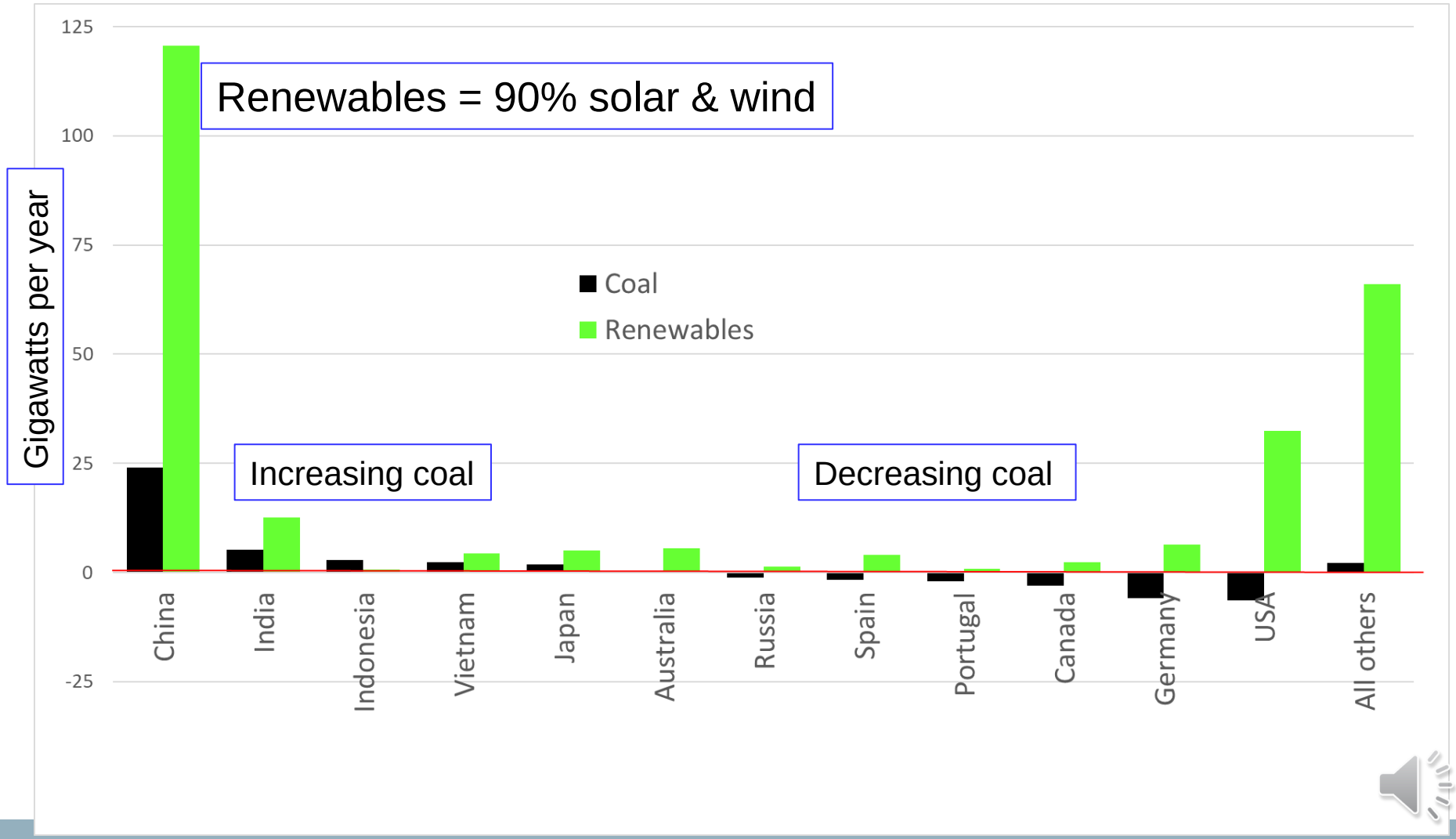
Solar & wind are unconstrained

Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Global annual net new generation capacity



Net new coal and renewables capacity in 2021

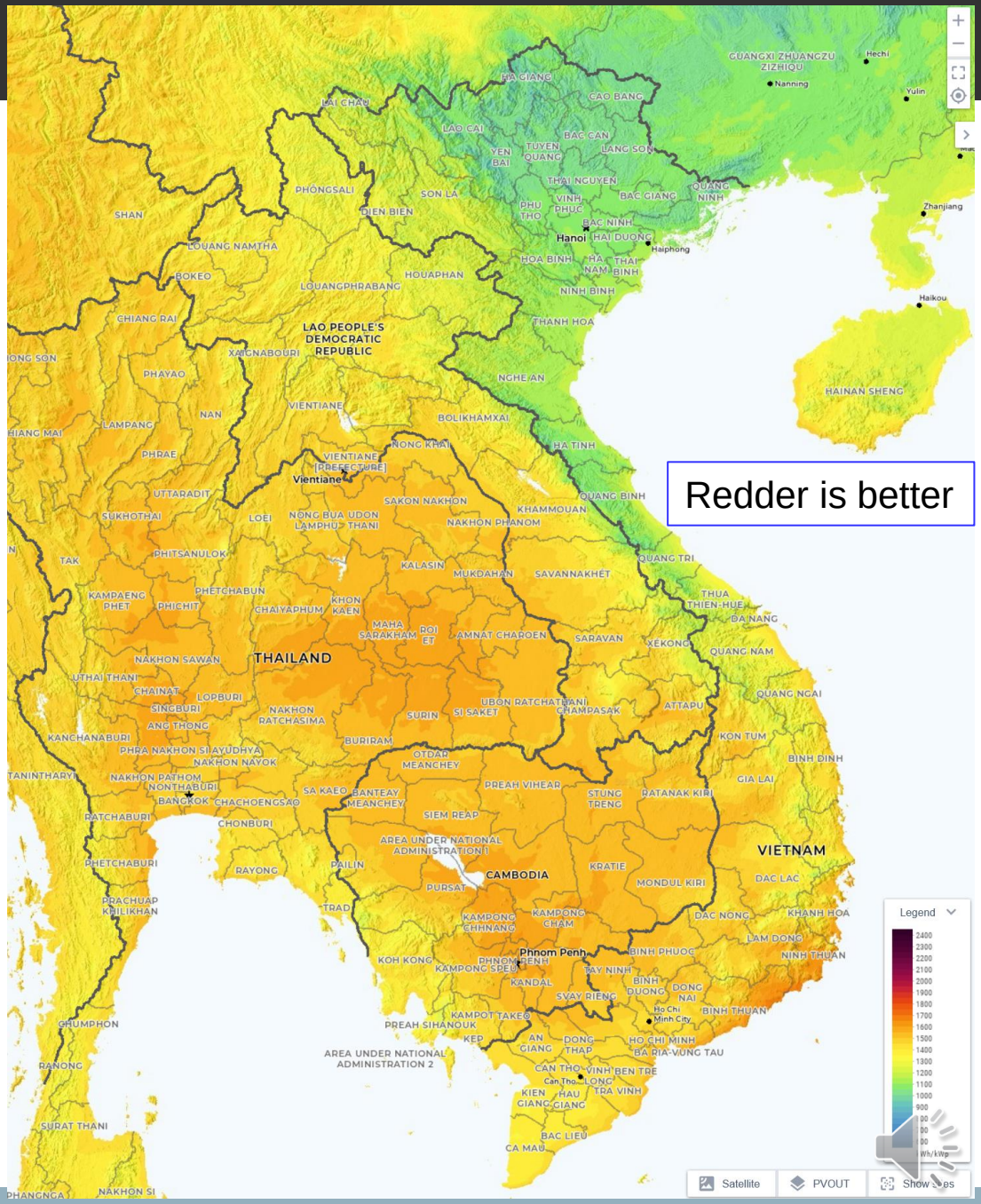


Solar & wind are unconstrained

Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Australian National University

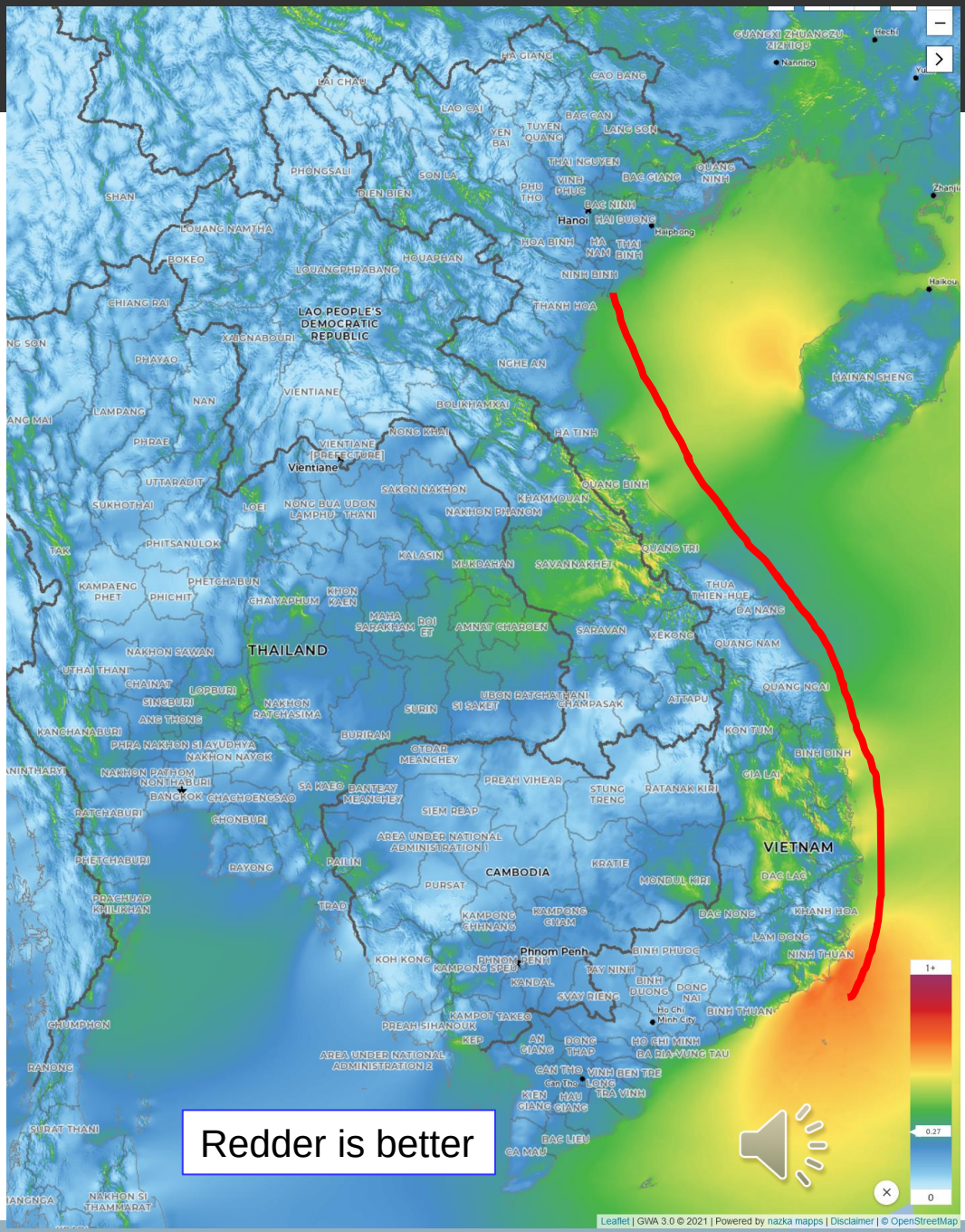
Vietnam solar:
- good in the south
- poor in the north



Australian National University

Vietnam has world-class offshore wind

Offshore north-south HVDC cables allow sharing of solar and wind



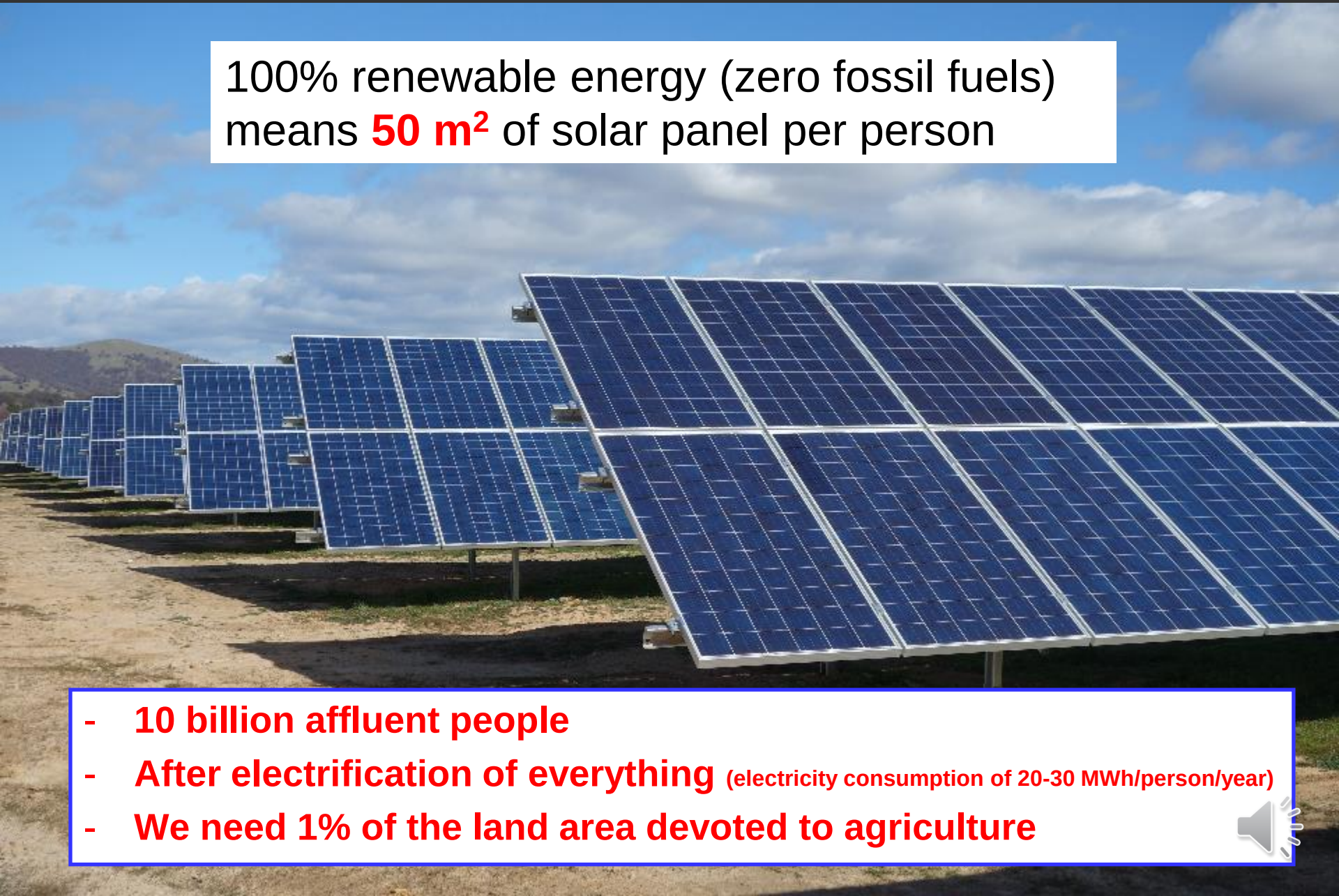
https://globalwindatlas.info/

Solar & wind are unconstrained

Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Australian National University

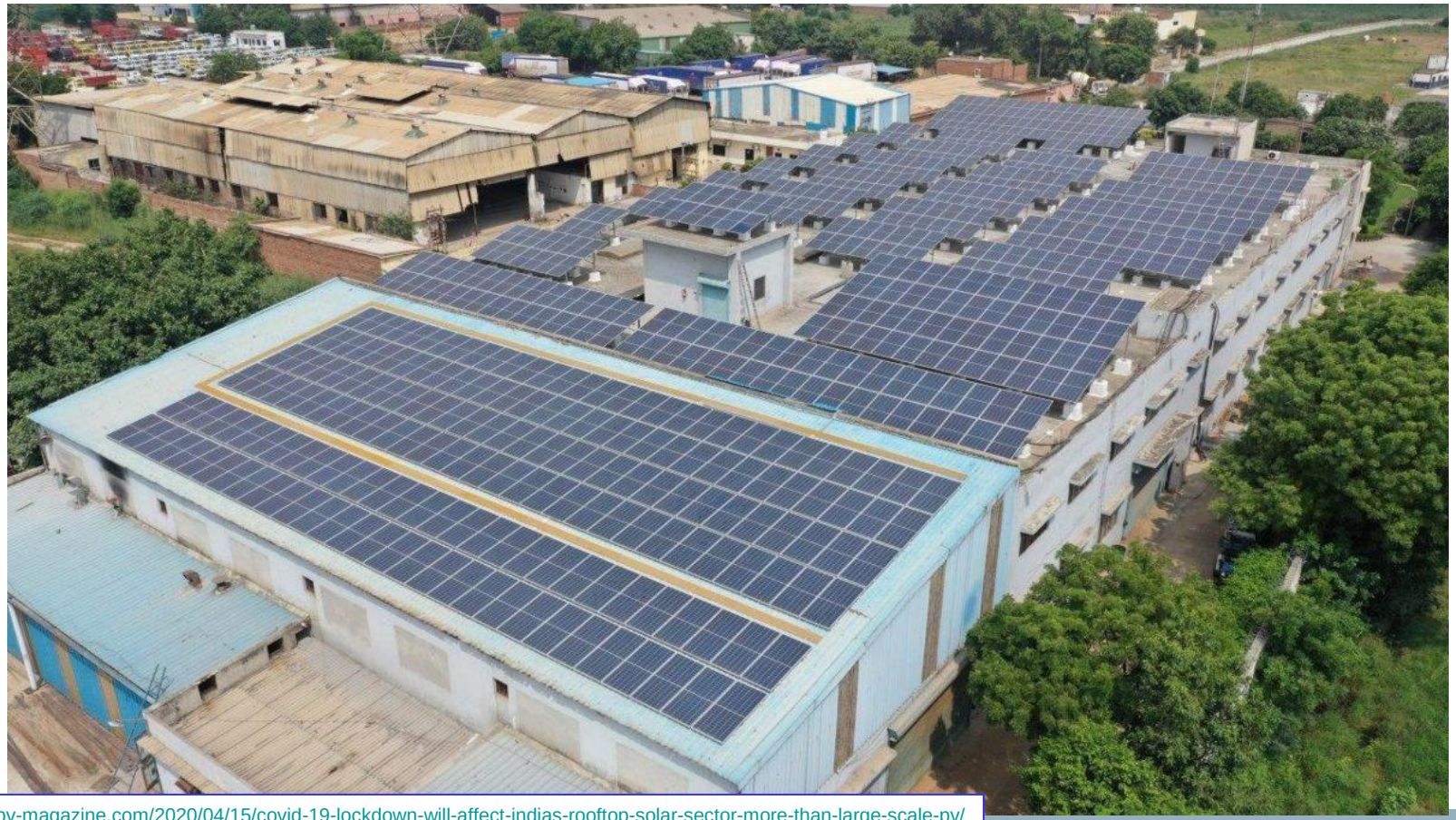
100% renewable energy (zero fossil fuels) means **50 m^2** of solar panel per person



- **10 billion affluent people**
- **After electrification of everything** **(electricity consumption of 20-30 MWh/person/year)**
- **We need 1% of the land area devoted to agriculture**

Rooftop solar

- Cheap energy almost everywhere
- 30% of Australian houses have solar



https://www.pv-magazine.com/2020/04/15/covid-19-lockdown-will-affect-indias-rooftop-solar-sector-more-than-large-scale-pv/

Agrivoltaics

- Billions of solar panels in combination with agriculture
  → small loss of food production
  → second cash crop for farmers
- Dual use of 1% of agricultural land provides enough energy for 10 billion affluent people with full electrification and zero fossil fuels

https://www.smart-energy.com/renewable-energy/agrivoltaic-worlds-energy-needs-can-be-powered-by-farmland-based-solar/

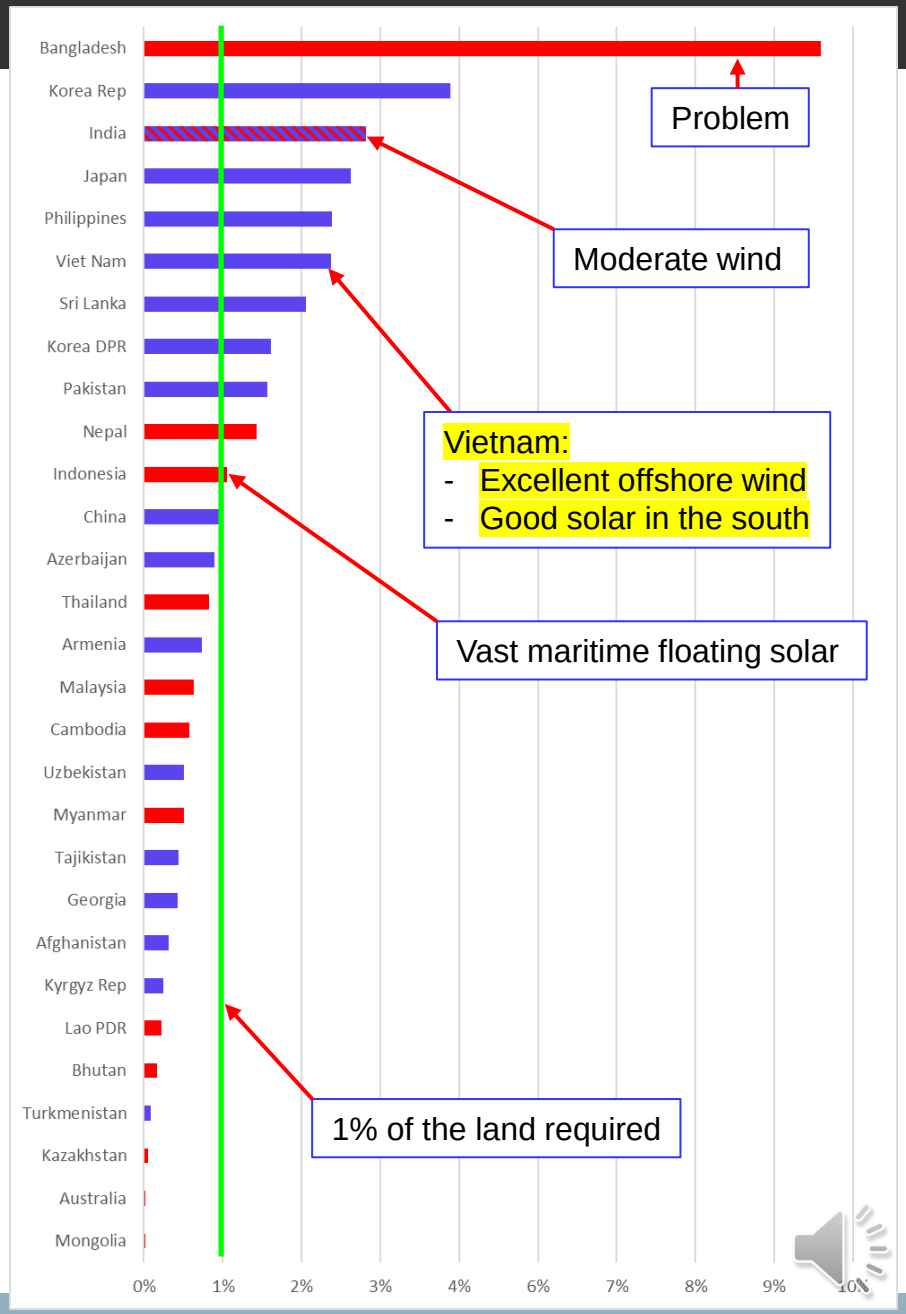
Australian National University

Land requirements (%)

Assumptions:

- Wealthy population (≡ USA, EU)
- Full electrification, zero fossil fuels
- **All** energy comes from solar
  - 20 MWh/person/year

Blue = lots of wind
Red = not much wind



Solar & wind are unconstrained

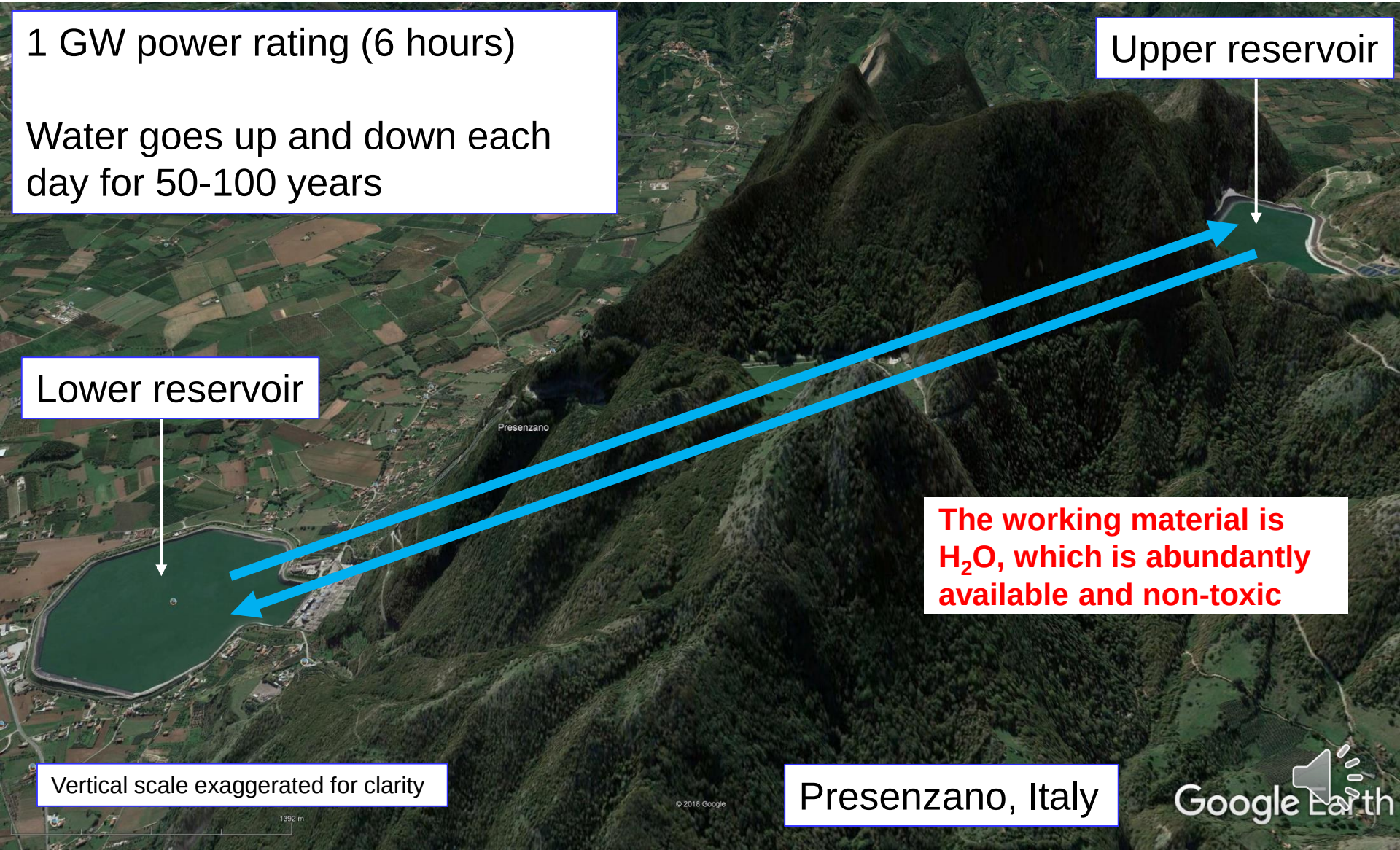
Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Balancing intermittency is a solved problem

- Technical diversity
  - PV and wind (+ existing hydro)
- Wide geographical dispersion (0.1-1 million km^2)
  - Reduces storage by smoothing-out local weather
- Demand management
  - Shift loads from night to day, interruptible loads
- Mass storage is a solved problem
  - Pumped hydro: 95% of all storage
  - Batteries
  - Heat stores

Australian National University

Off-river pumped hydro



Australian National University

ANU's global off-river pumped hydro atlas

http://re100.eng.anu.edu.au/global/index.php

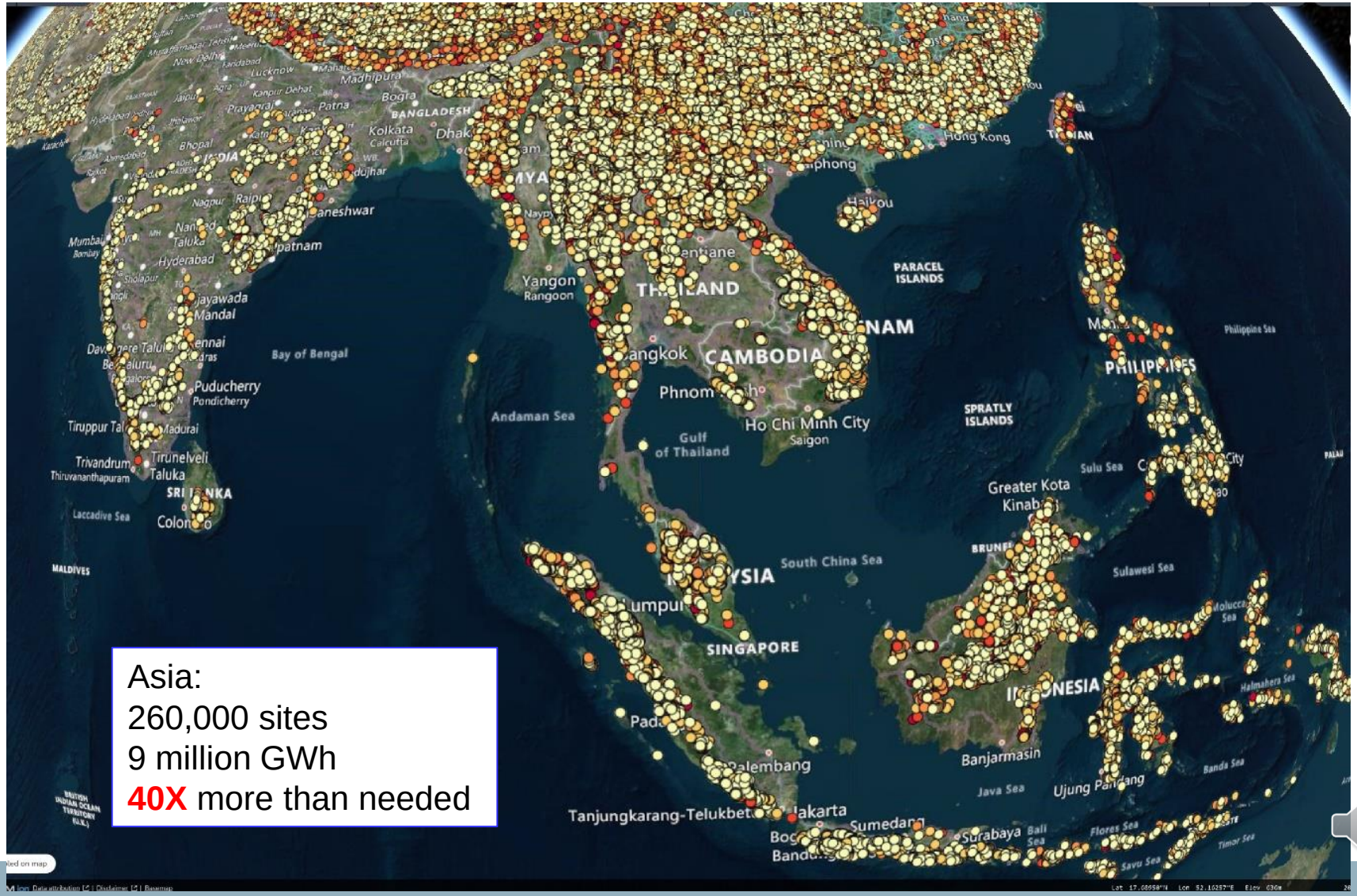
616,000 off-river sites (60°N to 56°S)

23 million Gigawatt-hours (1 million GW * 23 hours)

All outside national parks & urban areas

Australian National University

50 GWh pumped storage in Asia



Australian National University

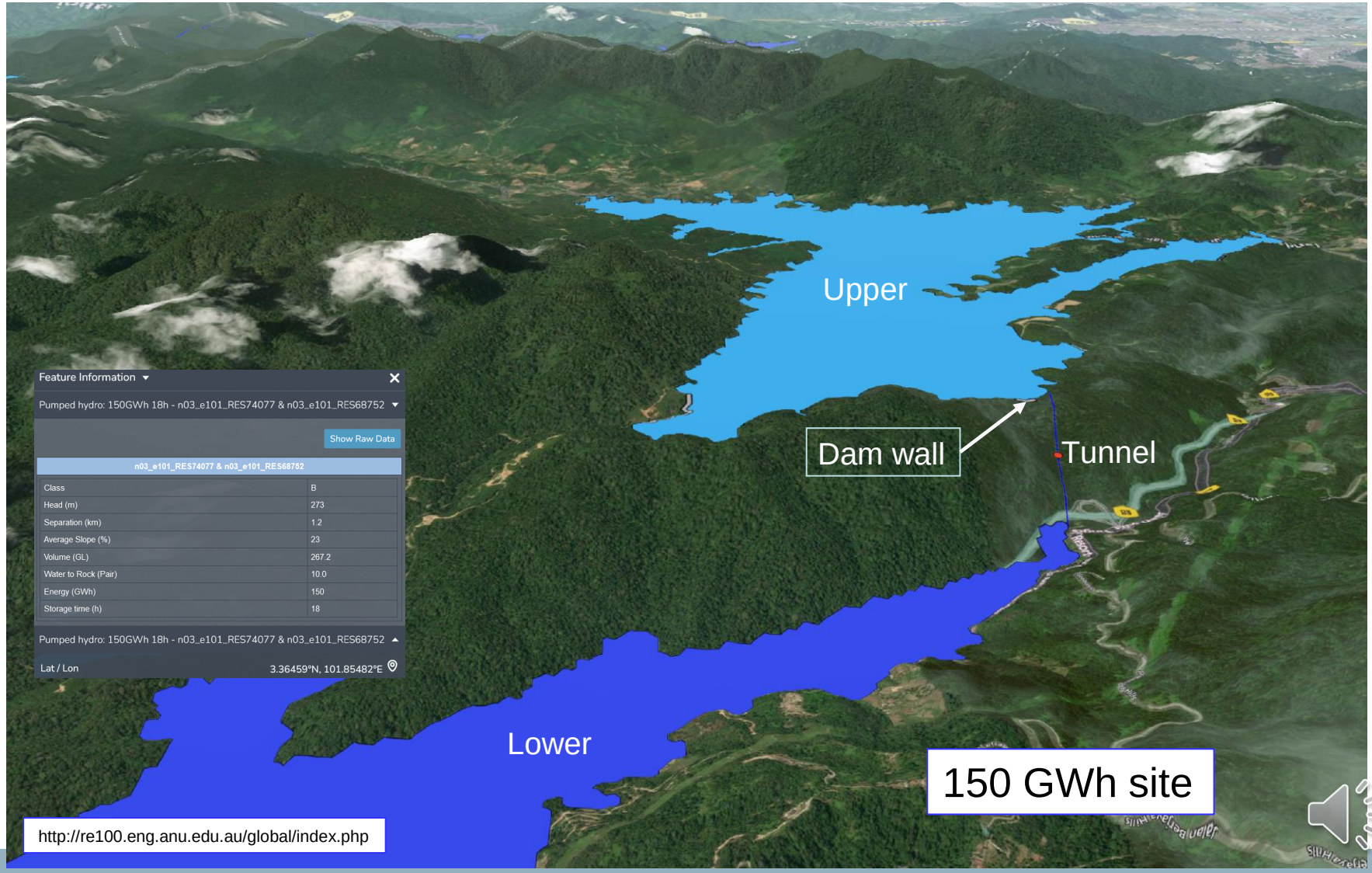
Vietnam's enormous pumped hydro resource:
- 6,000 sites
- 200 Terawatt-hours
(50X more than needed)

Snowy 2.0 (Australia)

350 GWh, 2 GW
Cost: US$10/GWh

Australian National University

3-D image + information pop-up



http://re100.eng.anu.edu.au/global/index.php

Off-river vs on-river PHES

- Vastly more **off-river** sites (100-fold)
- Low technical risk
  - No rivers
  - No flood control costs
- Construction time: 2-5 years
- Small footprint
  - **100 hectare** reservoirs, 25m deep, 500m head

  → **1 GW for 24 hours**

Pumped hydro - environmental

- All sites are outside national parks
- Combined reservoir area is small
  - **3 m^2 per person to support 100% renewables**
- Water requirement is small
  - **3 litres per person per day to support 100% renewables**
- Water use for 100% renewables is 10X less than coal (no cooling towers)

Cost of pumped hydro

- Cost of energy ($/GWh)
  - Two reservoirs
- Cost of power ($/GW)
  - Tunnel
  - Pump/turbine & powerhouse
  - Switchyard & transmission
- $Total cost = $energy + $power

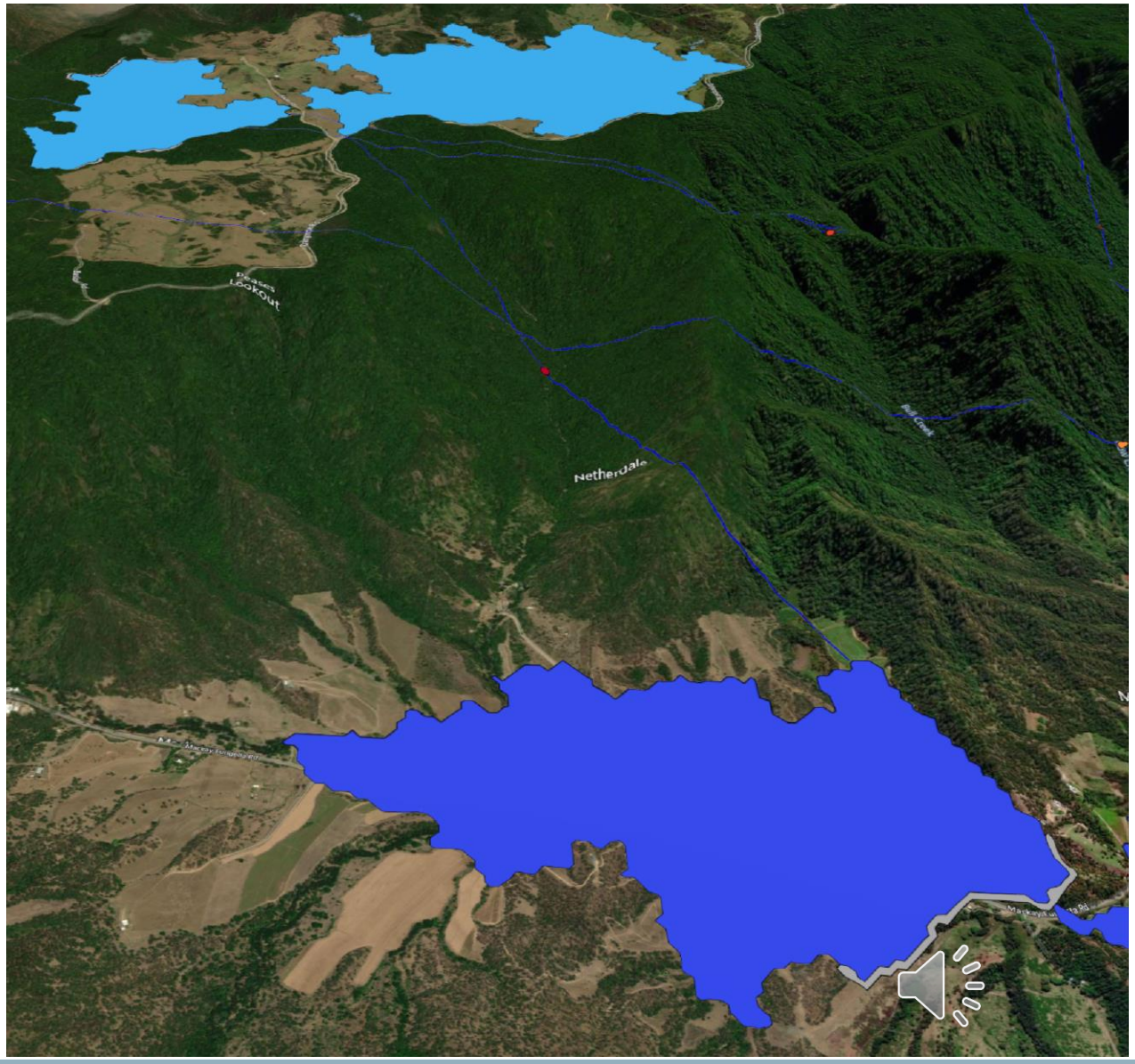
Main cost drivers

- Head: bigger is better: 500-800 m
  - Triple head = half capital cost per unit of storage
- Scale: bigger is better: Gigawatt-scale, 15-150 GWh
- Reservoirs
  - Main cost is moving rock to make the dam walls
  - Desirable: small rock wall, large water storage, large head
- Pressure tunnel
  - Separation distance should be small with large head
- Electromechanical & powerhouse
  - Large head reduces cost

Australian National University

Pioneer Valley
Mackay, Qld

Class A
5 GW
50-120 GWh
Head: 700m
Slope: 17%
W/R ratio: 13



Example: Snowy 2.0

- Under construction
  - US$4-6 billion
  - 350 GWh (energy)
  - 2 GW (power)
- Bigger than all utility batteries in the world combined
- US$15/kWh
  - far cheaper than batteries for overnight storage

Solar & wind are unconstrained

Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Solar & wind avoid:

- greenhouse gas emissions
- energy exports & imports
- car exhausts
- smokestacks
- urban smog
- oil spills
- oil-related warfare
- fracking for gas
- open-cut coal mines
- coal mine fires
- ash dumps
- flooding of rivers for hydroelectricity
- nuclear waste
- nuclear accidents
- nuclear weapons proliferation

Solar & wind are unconstrained

Issue	Resolution
Cost and competition	The market has spoken: solar & wind are cheapest
Solar & wind resources	Vast in most countries
Land	Unlimited in most countries
Balancing intermittency	Off-the-shelf solutions
Environmental impact	Low
Critical minerals	All materials are substitutable

Critical minerals are substitutable

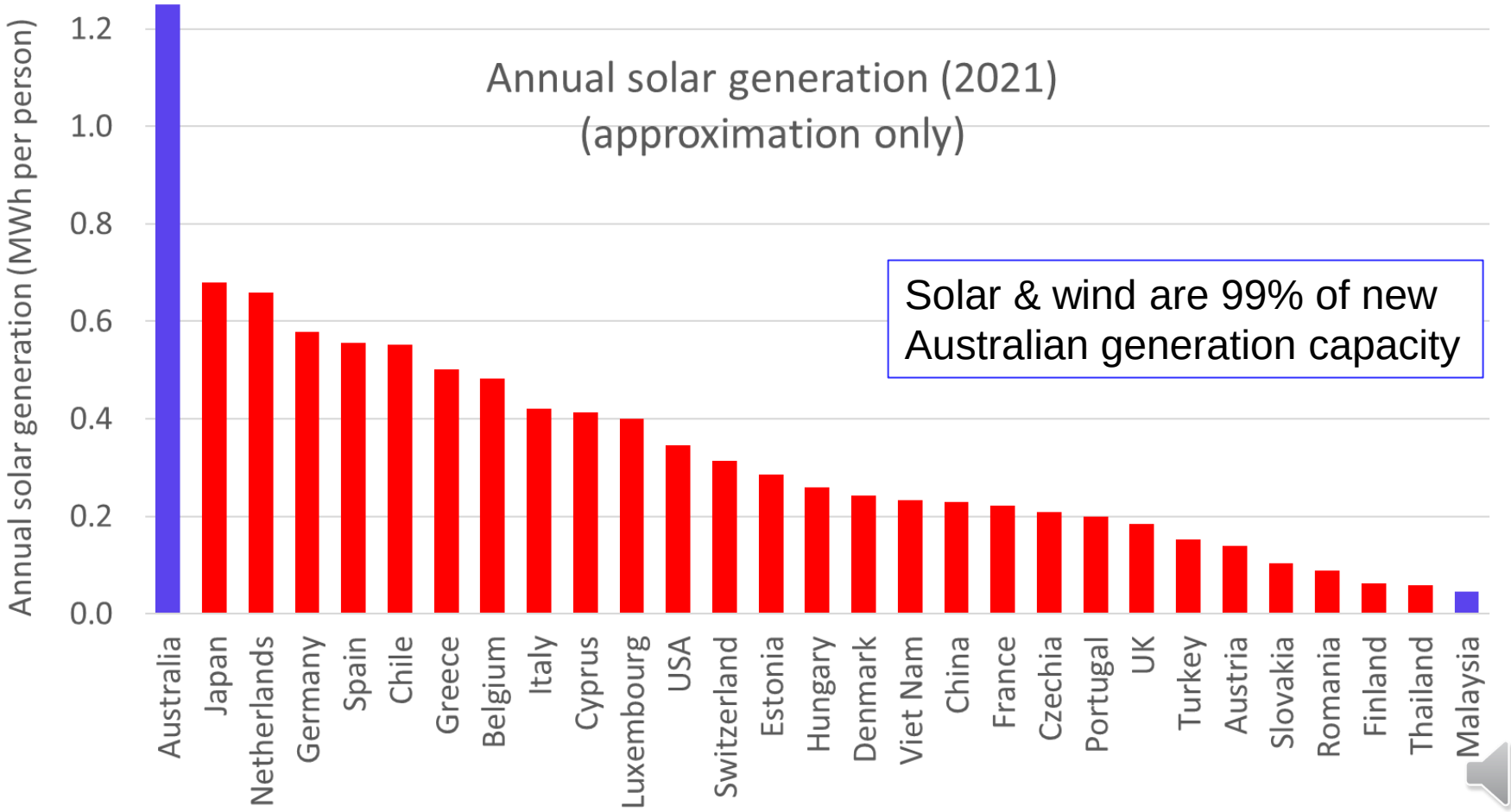
- Many technological ways around scarce metals
  - Eg Tesla vehicle batteries moving away from nickel and cobalt
- Scarcity increases price → substitution
- Occasional supply bottlenecks occur, as with any rapidly growing industry

The importance of pathfinding

- Australia is the global solar pathfinder
  - physically isolated
  - not much hydro
  - tracking towards 80-90% renewables in 2030
  - South Australia tracking towards 100% solar/wind in 2026
  - highly stable grid.
- Letting the market sort it out via **price discovery**

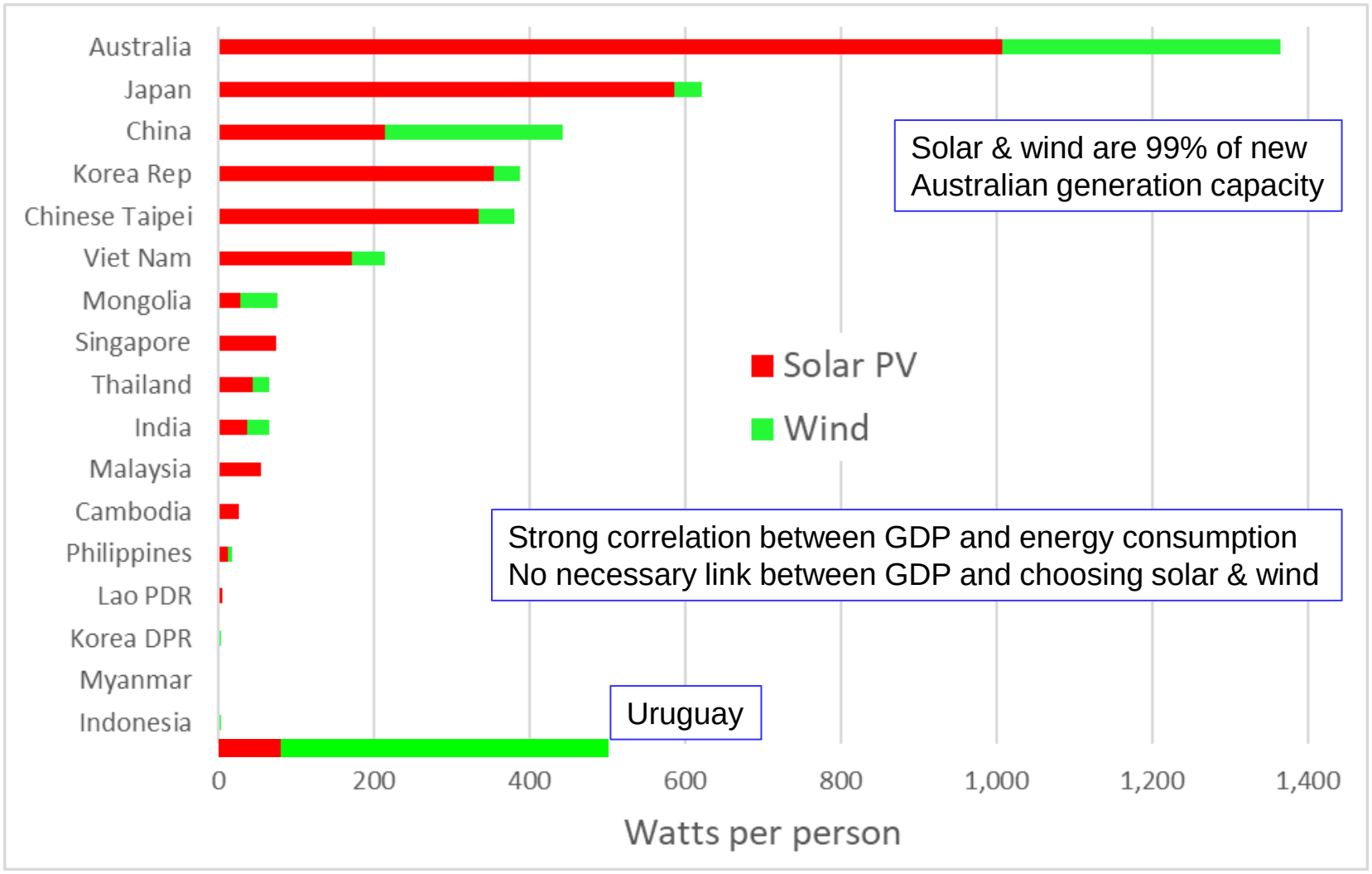
Solar generation per person per year

Australia: global solar pathfinder



Solar & wind are 99% of new Australian generation capacity

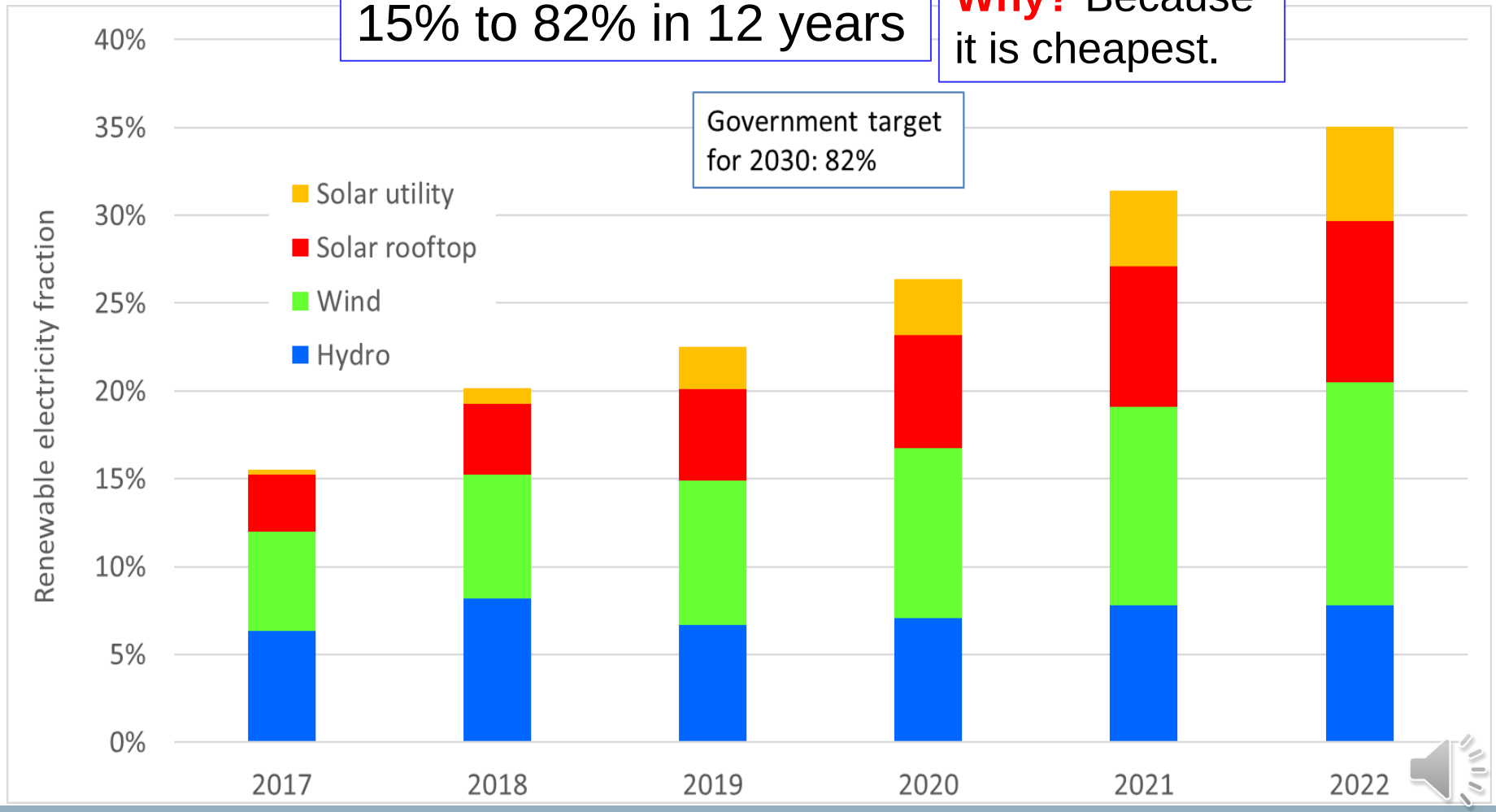
Per capita solar & wind in Asia



Australian renewable electricity

15% to 82% in 12 years

Why? Because it is cheapest.

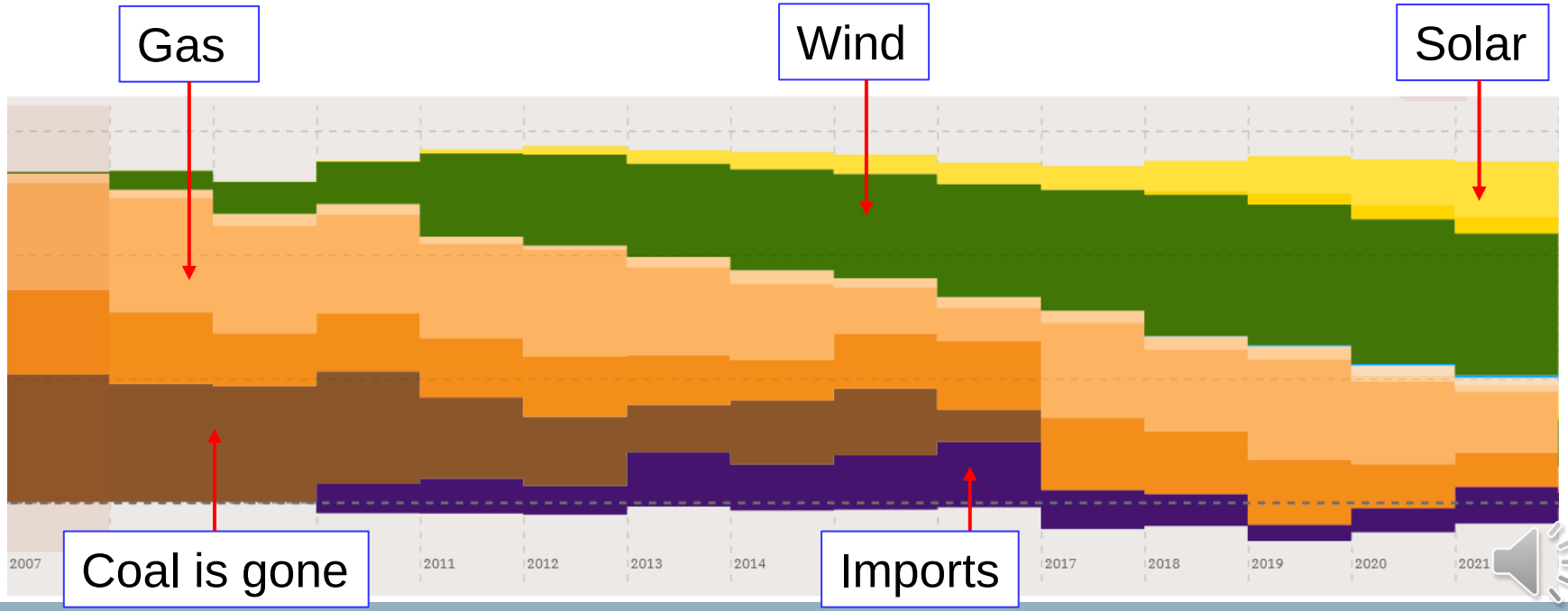


South Australia – global leader

- Solar & wind supply 70% of electricity
- Tracking towards 100% solar & wind in 2025
- Highly stable Gigawatt-scale grid

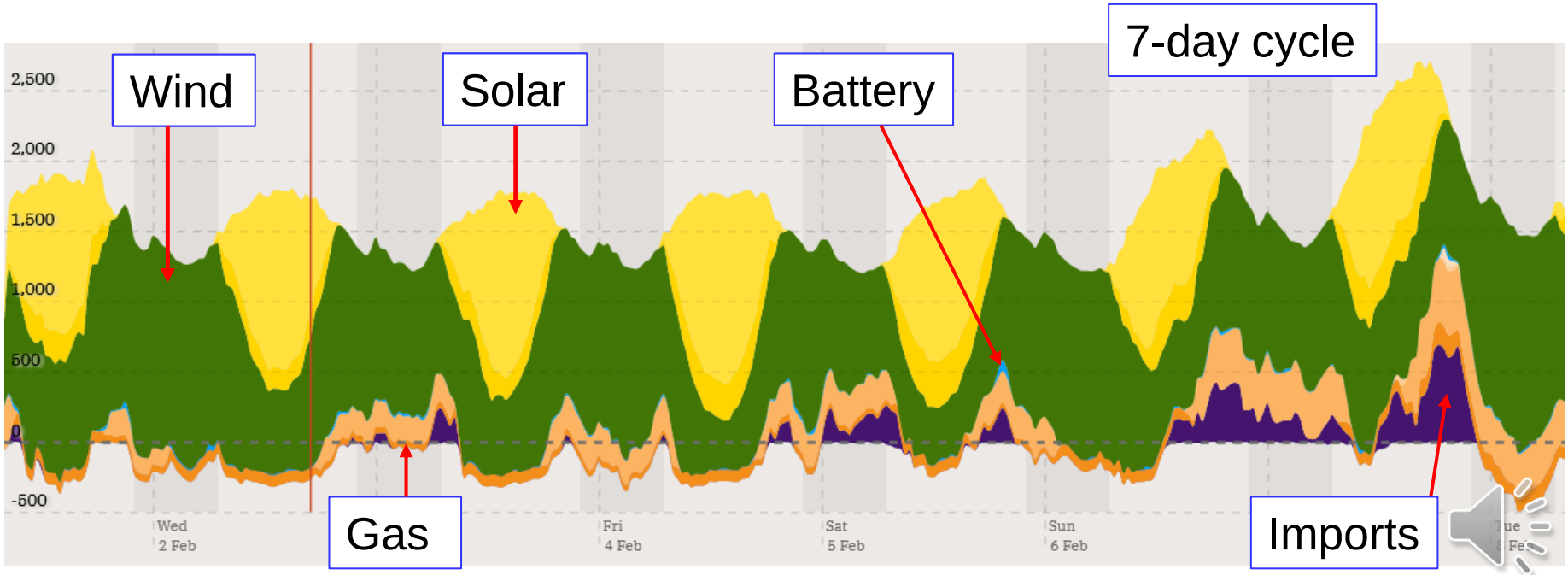
Why? Because it is cheapest.

0% to 100% in 18 years



South Australia

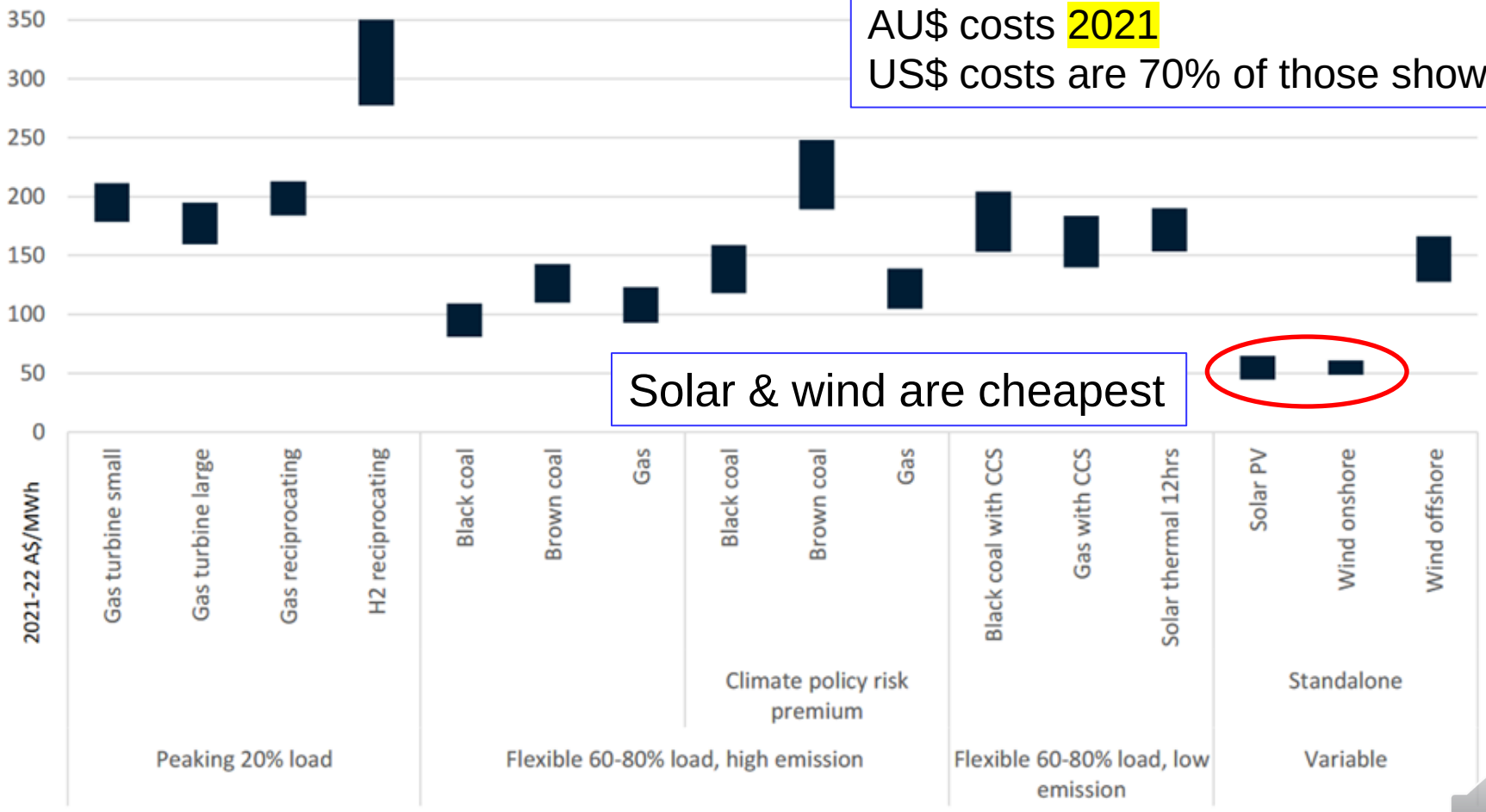
- 1st week in February 2022: solar + wind = 89%
- Peak hour : solar + wind = 136%
- Wholesale price of electricity Jan-April 2022 = lowest



Australian National University

Levelized energy cost for new plant

Australian consensus numbers
AU$ costs 2021
US$ costs are 70% of those shown



Solar & wind are cheapest

https://www.csiro.au/en/news/News-releases/2022/GenCost-2022

Facts on the ground: new Australian energy infrastructure

Bigger than all utility batteries in the world put together

	Technology	Power (GW)	Energy (GWh)	Comments
Tumut 3	Pumped hydro	0.6/1.8	60	Existing
Kangaroo Valley	Pumped hydro	0.2	<1	Existing
Wivenhoe	Pumped hydro	0.6	6	Existing
Snowy 2.0	Pumped hydro	2.0	350	Under construction
Kidston-Genex	Pumped hydro	0.3	2	Under construction
State Government announcements: Tasmania (Battery of the Nation), Qld (Pioneer-Burdekin, Borumba), Victoria, NSW	Pumped hydro	12	5-150	Announced
Utility combined	Batteries	3.0	3	Existing
Household combined	Batteries	-	1	Existing
EV combined	Batteries	-	1	Existing
Marinus Link	Transmission	1.2	-	Approved
Energy Connect	Transmission	0.8	-	Approved
HumeLink, QNI, VNI, VNI-West, Central-West Orana REZ, Snowy 2.0 connection and others	Transmission			Feasibility studies and detailed planning

No new dams on rivers

Keeping the lights on

Straightforward, off-the-shelf

- Strong regional interconnection to smooth out local weather
- Demand management in its myriad forms
- Load-following legacy coal & gas
- Hydro storage
- Pumped hydro energy storage
- Batteries: utility, home, electric vehicle
- Hot water storage tanks
- The building fabric
- Thermal stores in factories (charged during daylight) to displace gas combustion: hot rocks, molten salt molten silicon, etc

Come and see how Australia is doing it

Putting it together

- Solar & wind **decisively** won the energy race
- They produce the cheapest electricity
- They will do the heavy lifting to get rid of fossil fuels

Estimated cost of energy in Vietnam: US$75/MWh

Generation + storage + transmission

https://www.sciencedirect.com/science/article/pii/S0360544221016352

Low emissions technology

Net capacity deployment rates (GW/yr)

> 50,000 GW in mid-century

Technology	GW/year	
Solar & wind	240	Doubling every 4 years
Hydroelectricity	25	Not enough rivers to dam
Bio energy	6	Awful (<1%) conversion efficiency
Nuclear	0	Expensive, slow
Carbon capture & storage	0	Too expensive
Solar thermal, geothermal	1	Very small global deployment

Extravagant growth rates needed to become significant in 2050

Solar PV = 25% efficiency (sunshine-to-useful-energy)

Getting on the quick path – use the market!

- Encourage rooftop solar
  - Very cheap electricity everywhere
  - Utilise private capital
  - Sort out supply chains and skills
- Free market for new generation capacity
  - Price discovery = solar & wind are cheap!
- Remove (or equalize) fossil fuel subsidies

National energy independence

- Make your own solar & wind electricity
- Energise your own electric transport
- Make your own electro chemicals
- Cease importing oil, gas & coal

Trade war

Invasion

Pandemic

Developing Asia

Distributed cheap solar energy for energy-poor rural people:

- Lighting
- Water pumping
- Grain grinding
- Computers
- Mobile phones and telecommunications
- Transport
- Cooking
- Light industry

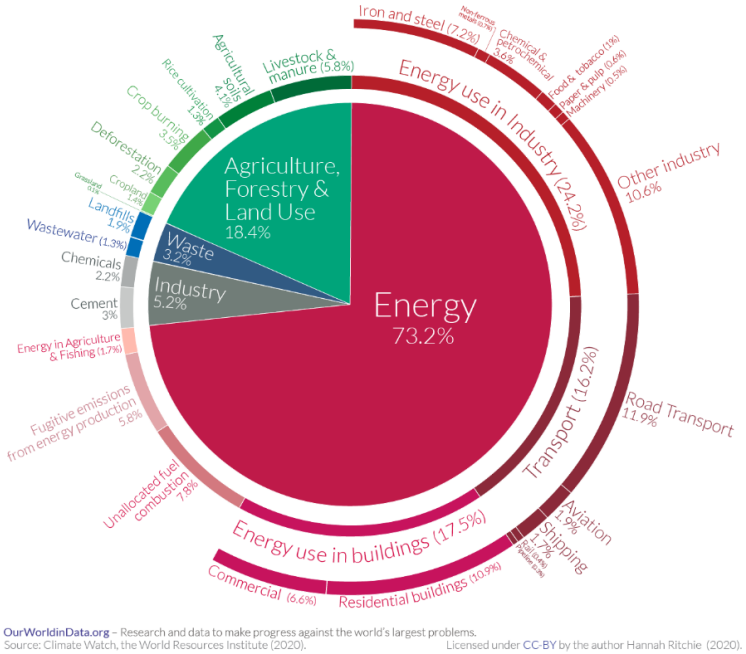
Rural electrification:
Rooftop solar + microgrids are more effective than central power + grid extension

Transport
1 kW panel + battery, 25 year lifetime = **0.2** tonnes
Equivalent diesel fuel = **10** tonnes → 27 tonnes CO_2

Flexible solar: the first 100 Watts is worth more than the next 1000 Watts

Zero energy emissions in mid century is straightforward

Let free market price discovery work



- Build solar & wind generators
  - **Stop** building coal & gas power plan
- Buy electric vehicles
  - **Stop** buying oil powered vehicles
- Buy electric heaters
  - **Stop** buying gas heaters & furnaces
- Existing fossil fuel machines get old and **retire** before 2050

  → Get rid of all fossil fuels

Future of energy in Vietnam

Vietnam attributes

- Large solar resource with low seasonal variation
- Large offshore wind
- Plenty of space: rooftop, agrivoltaics
- Large, low cost, pumped hydro storage resource

A solar and wind future for an affluent Vietnam

- Strongly connect north and south with an offshore HVDC cable
- Electrification of nearly everything (transport, heating, industry)
- **500-1000 GW** of solar PV and wind (with support from hydro)
- Solar & wind build rate: **10-20 GW per year** to complete the job by mid-century
- **100-200 GW** of storage (PHES + batteries)

80% reduction in emissions by 2035

- Generation
  - Solar PV – rooftop, agri-PV, floating - unlimited
  - Wind
- Balancing
  - Strong transmission interconnection between regions
  - Pumped hydro storage (off-river) - unlimited
  - Batteries (utility, electric vehicles)
  - Demand management
- Electrification
  - Electric vehicles
  - Electric heat pumps
  - Electric furnaces

- Mature, vast production runs
- Infinite material supply, infinite resource base
- Low environmental cost
- Nothing to invent – the cheapest energy in history
- And lots of room to further lower costs

Summary – the fastest energy change in history

- The market has spoken: solar & wind are cheapest
  - Let the market sort it out via price discovery
- Plenty of rooftops and land/sea for solar & wind
- Energy storage is a solved problem
- Energy independence for most countries

Key message: stop acquiring fossil fuel machines
→ Remove ¾ of global emissions at low cost

If in doubt: come see what is happening in Australia


Thank you!
http://re100.eng.anu.edu.au