Energy in Vietnam

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

Net new global capacity additions in 2021

Solar + wind = ¾ of net new generation capacity

Coal + oil + gas + nuclear + hydro + geothermal + bioenergy + solar thermal
The power of sustained exponential growth

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

Global installed solar PV capacity (Terawatts)

- Solar deployment exponential growth rate = 25%
- Solar target for zero fossil fuels in 2050 = 60 TW

- Pass nuclear in 2017
- Pass Hydro in 2023
- Pass coal in 2026

## Solar & wind are unconstrained

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The market has spoken: solar PV and wind decisively won the energy race.
Net new coal and renewables capacity in 2021

Renewables = 90% solar & wind

Gigawatts per year

Increasing coal

Decreasing coal
Solar & wind are unconstrained

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

Redder is better
Vietnam has world-class offshore wind

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

Redder is better

https://globalwindatlas.info/
Solar & wind are unconstrained

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100% renewable energy (zero fossil fuels) means $50 \text{ m}^2$ 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
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
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**

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Balancing intermittency is a solved problem

- **Technical diversity**
  - PV and wind (+ existing hydro)

- **Wide geographical dispersion (0.1-1 million km²)**
  - 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
**Off-river pumped hydro**

1 GW power rating (6 hours)

Water goes up and down each day for 50-100 years

The working material is $\text{H}_2\text{O}$, which is abundantly available and non-toxic

Vertical scale exaggerated for clarity

Presenzano, Italy
ANU’s global **off-river** pumped hydro atlas


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
50 GWh pumped storage in Asia

Asia:
260,000 sites
9 million GWh
40X more than needed
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
3-D image + information pop-up

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
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

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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

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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

Annual solar generation (2021)
(approximation only)

Solar & wind are 99% of new Australian generation capacity
Per capita solar & wind in Asia

- Australia: Solar PV 1,000, Wind 130
- Japan: Solar PV 800, Wind 400
- China: Solar PV 600, Wind 200
- Korea Rep: Solar PV 400, Wind 100
- Chinese Taipei: Solar PV 300, Wind 100
- Viet Nam: Solar PV 200, Wind 100
- Mongolia: Solar PV 100, Wind 50
- Singapore: Solar PV 100, Wind 50
- Thailand: Solar PV 100, Wind 50
- India: Solar PV 100, Wind 50
- Malaysia: Solar PV 100, Wind 50
- Cambodia: Solar PV 100, Wind 50
- Philippines: Solar PV 100, Wind 50
- Lao PDR: Solar PV 100, Wind 50
- Korea DPR: Solar PV 100, Wind 50
- Myanmar: Solar PV 100, Wind 50
- Indonesia: Solar PV 100, Wind 50

Solar & wind are 99% of new Australian generation capacity.

Strong correlation between GDP and energy consumption.
No necessary link between GDP and choosing solar & wind.

Uruguay: Solar PV 600, Wind 100
Australian renewable electricity

15% to 82% in 12 years

Why? Because it is cheapest.

Government target for 2030: 82%

- Solar utility
- Solar rooftop
- Wind
- Hydro

Yearly breakdown from 2017 to 2022.
South Australia – global leader

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

0% to 100% in 18 years

Why? Because it is cheapest.
South Australia

• 1\textsuperscript{st} week in February 2022: solar + wind = 89%
• Peak hour: solar + wind = 136%
• Wholesale price of electricity Jan-April 2022 = lowest
Levelized energy cost for new plant

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

Solar & wind are cheapest

### Facts on the ground: new Australian energy infrastructure

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<th>Technology</th>
<th>Power (GW)</th>
<th>Energy (GWh)</th>
<th>Comments</th>
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<tbody>
<tr>
<td>Tumut 3</td>
<td>Pumped hydro</td>
<td>0.6/1.8</td>
<td>60</td>
</tr>
<tr>
<td>Kangaroo Valley</td>
<td>Pumped hydro</td>
<td>0.2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Wivenhoe</td>
<td>Pumped hydro</td>
<td>0.6</td>
<td>6</td>
</tr>
<tr>
<td>Snowy 2.0</td>
<td>Pumped hydro</td>
<td>2.0</td>
<td>350</td>
</tr>
<tr>
<td>Kidston-Genex</td>
<td>Pumped hydro</td>
<td>0.3</td>
<td>2</td>
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**State Government announcements:**
- Tasmania ([Battery of the Nation](https://www.batteryofthenation.com.au)), Qld ([Pioneer-Burdekin, Borumba](https://www.pioneerburdekin.com.au)), Victoria, NSW
- Utility combined Bases: 3.0
- Household combined Batteries: - 1
- EV combined Batteries: - 1
- Marinus Link Transmission: 1.2
- Energy Connect Transmission: 0.8
- HumeLink, QNI, VNI, VNI-West, Central-West Orana REZ, Snowy 2.0 connection and others Transmission: Feasibility studies and detailed planning

**Bigger than all utility batteries in the world put together**

**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
## Low emissions technology

### Net capacity deployment rates (GW/yr)

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<td>Solar &amp; wind</td>
<td>240</td>
<td>Doubling every 4 years</td>
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<tr>
<td>Hydroelectricity</td>
<td>25</td>
<td>Not enough rivers to dam</td>
</tr>
<tr>
<td>Bio energy</td>
<td>6</td>
<td>Awful (&lt;1%) conversion efficiency</td>
</tr>
<tr>
<td>Nuclear</td>
<td>0</td>
<td>Expensive, slow</td>
</tr>
<tr>
<td>Carbon capture &amp; storage</td>
<td>0</td>
<td>Too expensive</td>
</tr>
<tr>
<td>Solar thermal, geothermal</td>
<td>1</td>
<td>Very small global deployment</td>
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> 50,000 GW in mid-century

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

Invasion

Pandemic

Trade war
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 CO₂

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 \( \frac{3}{4} \) of global emissions at low cost

If in doubt: come see what is happening in Australia
Thank you!

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