01

TIME FOR OPTIMISM

CHEAP ABUNDANT ENERGY IS COMING, SOONER THAN YOU THINK

The Exponential Agency
www.theexponential.agency

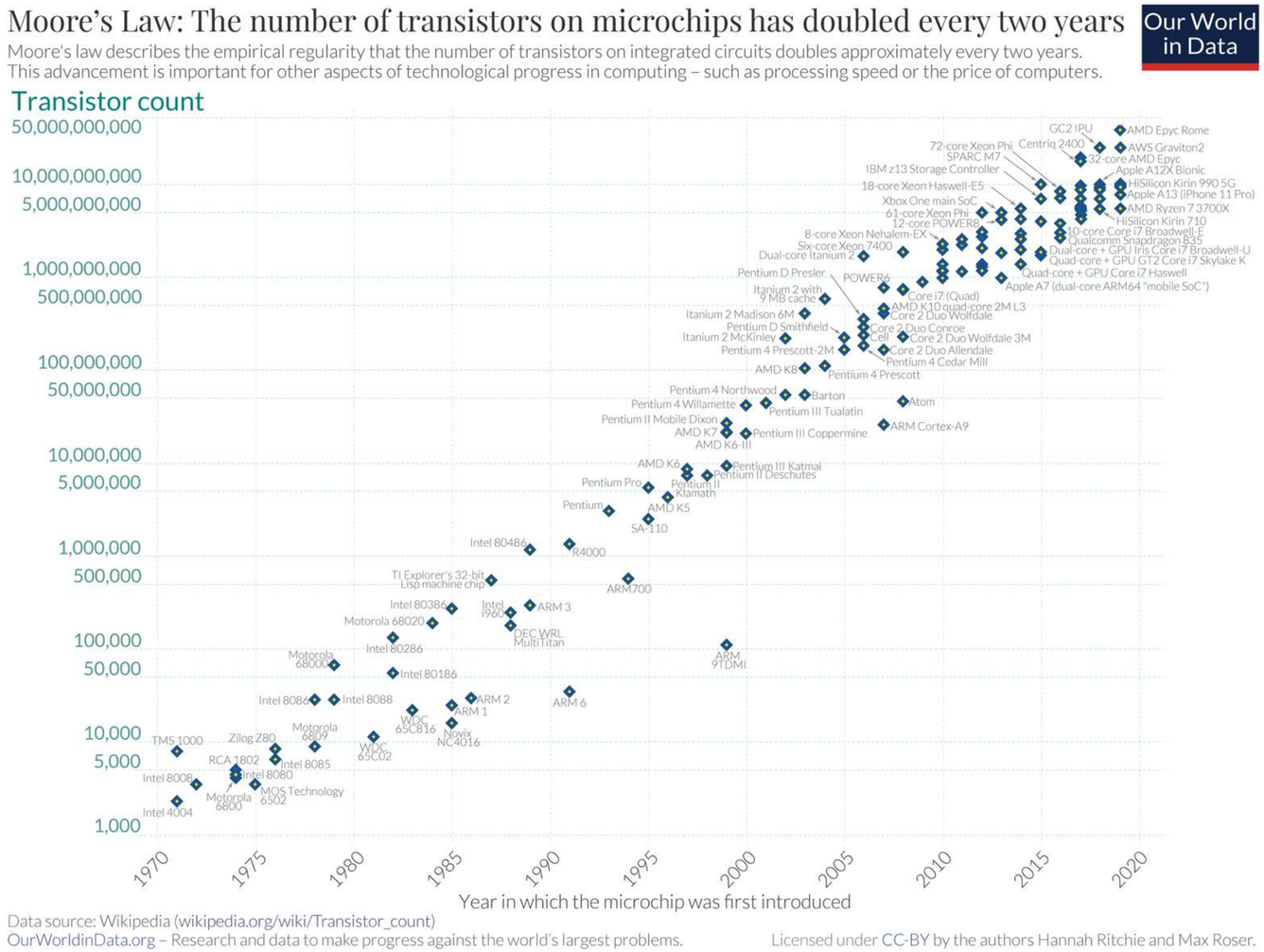
Author: Duane Fernandes

THE exponential AGENCY Powered by openexo

PART I: CHEAP ABUNDANT CLEAN ENERGY IS INEVITABLE

1. Exponential curves driven by hard science are predictable
2. Multiple exponential curves in action for energy
3. Solar-Wind-Battery is already cheaper and better than oil, coal, gas systems
4. No ‘Hail Mary’ required; the technology already exists
5. Low cost batteries resolves the intermittency issues of solar and wind generation
6. Now capitalism will take over making the transition inevitable

Exponential curves driven by hard science are predictable



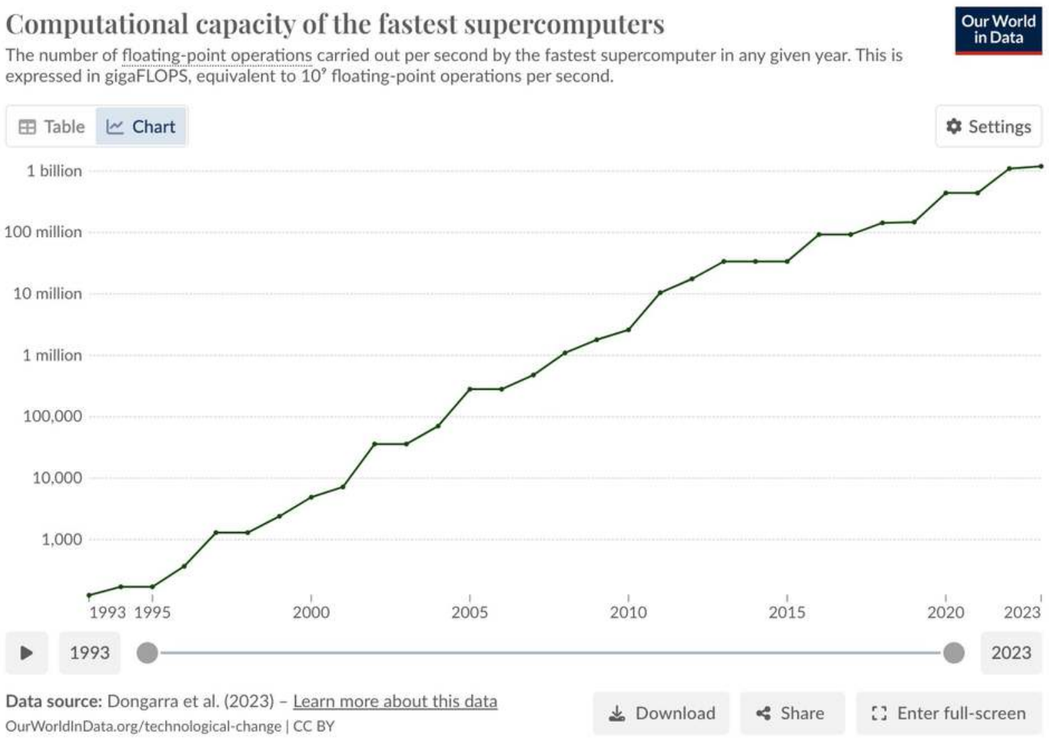
Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

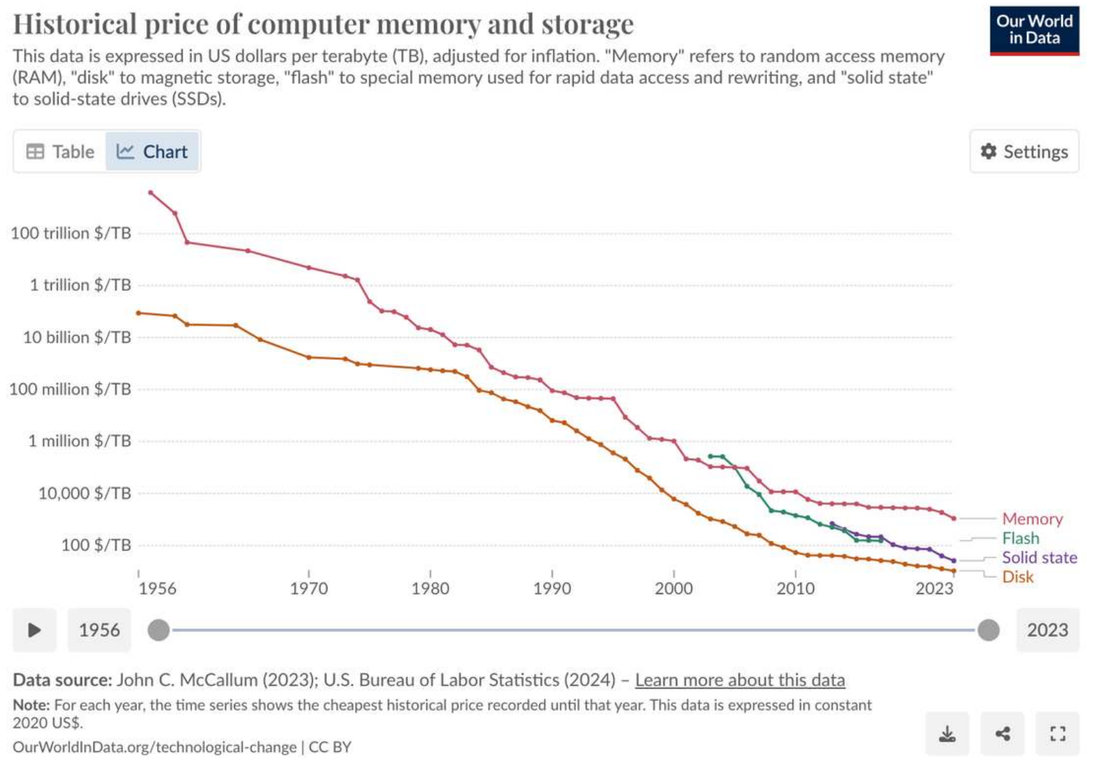
Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.

- The hard science is how many transistors can fit on an integrated circuit - not something that normal people care about
- The prediction of transistor count doubling every ~2 years was made in 1965
- Notice the log scale on the y-axis, that means an exponentially increasing rate of change

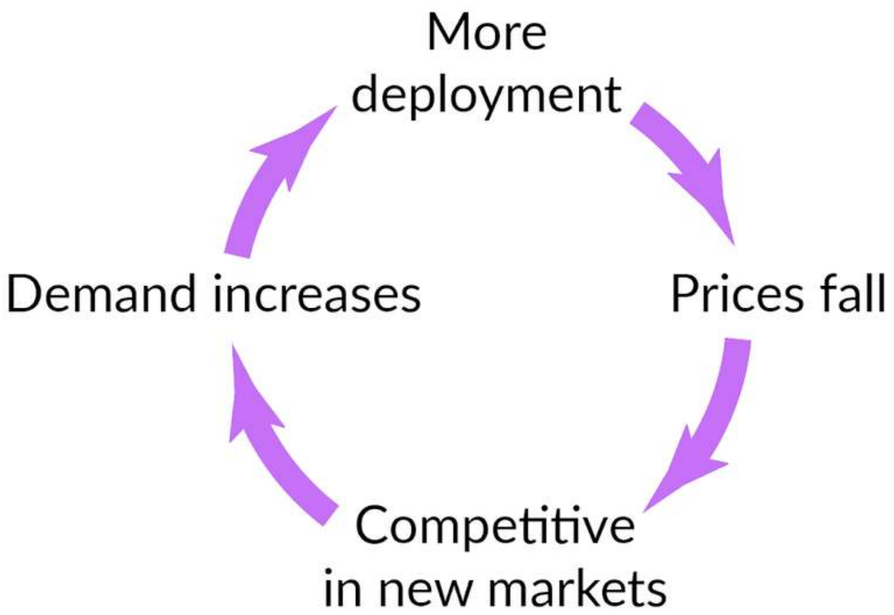
04

Scientific progress drives exponential improvement in things that matter to normal people, like speed and cost of things



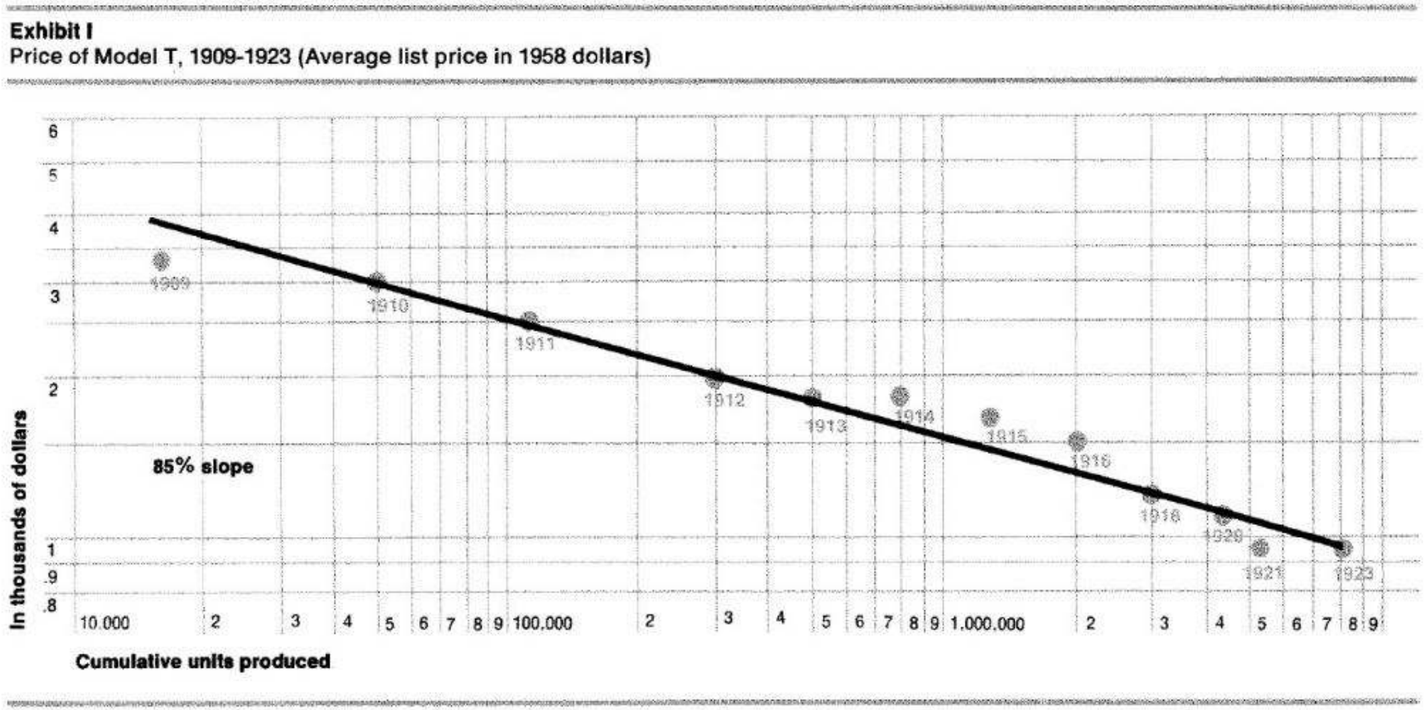


Technologies that become cheaper with increasing production enter a virtuous cycle; the learning rate is what drives down cost



The relative price decline associated with each doubling of cumulative experience is the learning rate of a technology.

The learning rate of the Ford Model T from 1909-1923 was 16% (every doubling of production led to a 16% price decline)

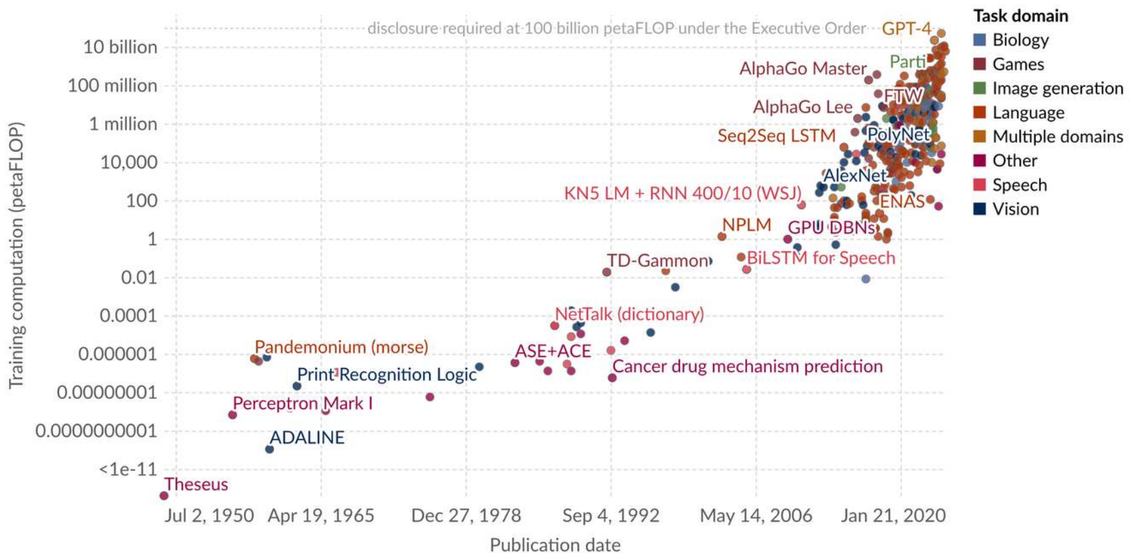


Exponential trends can stack on top of exponential trends; there are over 20 exponential technologies maturing together

Computation used to train notable artificial intelligence systems

Our World in Data

Computation is measured in total petaFLOP, which is 10^{15} floating-point operations[1]. Estimated from AI literature, albeit with some uncertainty. Estimates are expected to be accurate within a factor of 2, or a factor of 5 for recent undisclosed models like GPT-4.



Data source: Epoch (2024) OurWorldInData.org/artificial-intelligence | CC BY

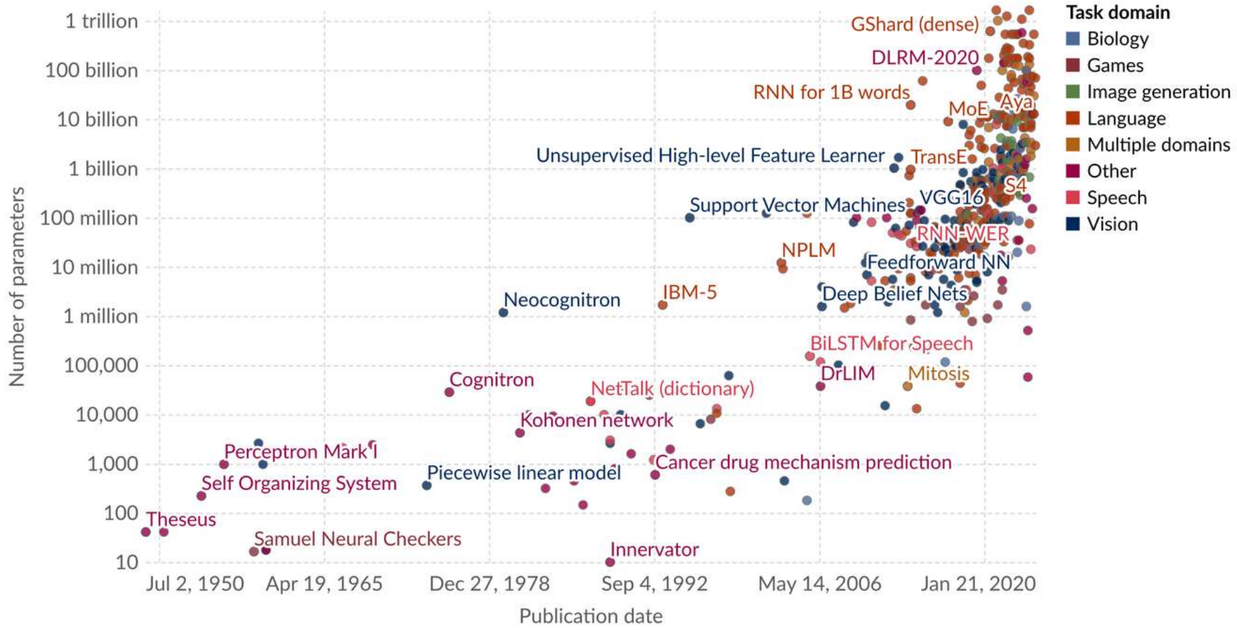
Note: The Executive Order on AI refers to a directive issued by President Biden on October 30, 2023, aimed at establishing guidelines and standards for the responsible development and use of artificial intelligence within the United States.

1. Floating-point operation: A floating-point operation (FLOP) is a type of computer operation. One FLOP represents a single arithmetic operation involving floating-point numbers, such as addition, subtraction, multiplication, or division.

Parameters in notable artificial intelligence systems

Our World in Data

Parameters are variables in an AI system whose values are adjusted during training to establish how input data gets transformed into the desired output; for example, the connection weights in an artificial neural network.

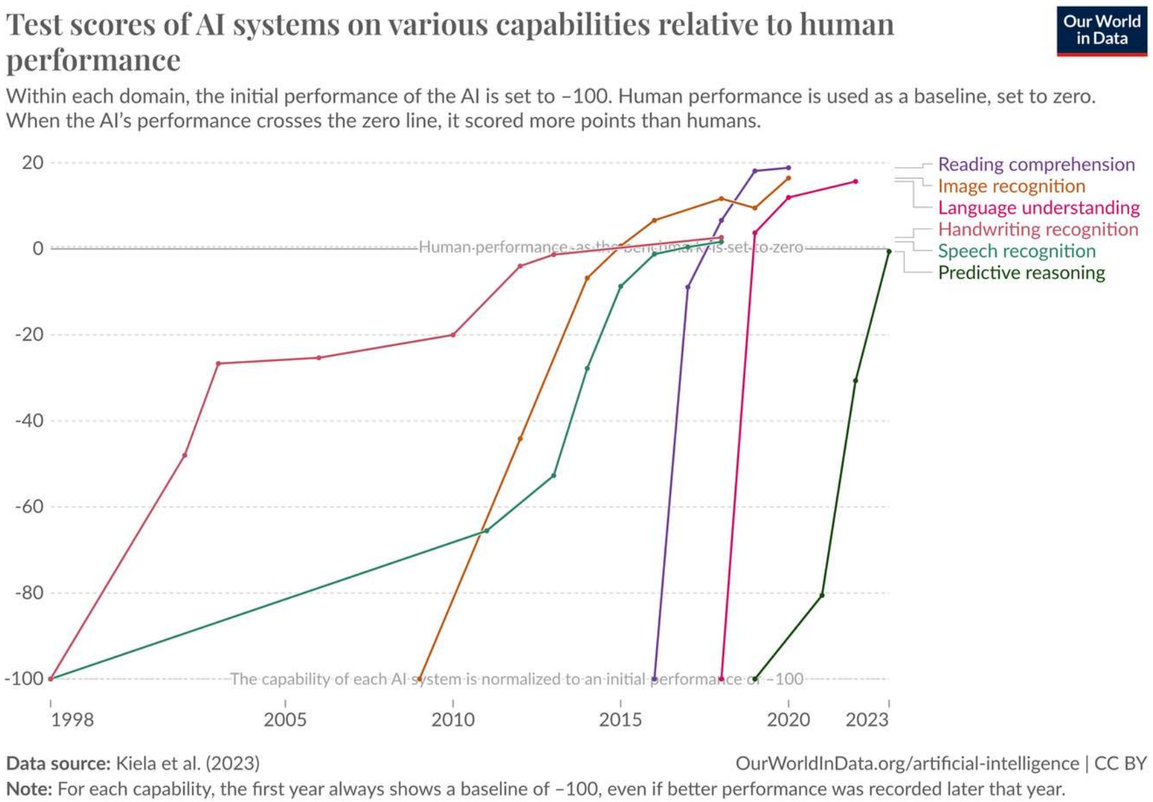


Data source: Epoch (2024) OurWorldInData.org/artificial-intelligence | CC BY

Note: Parameters are estimated based on published results in the AI literature and come with some uncertainty. The authors expect the estimates to be correct within a factor of 10.

07

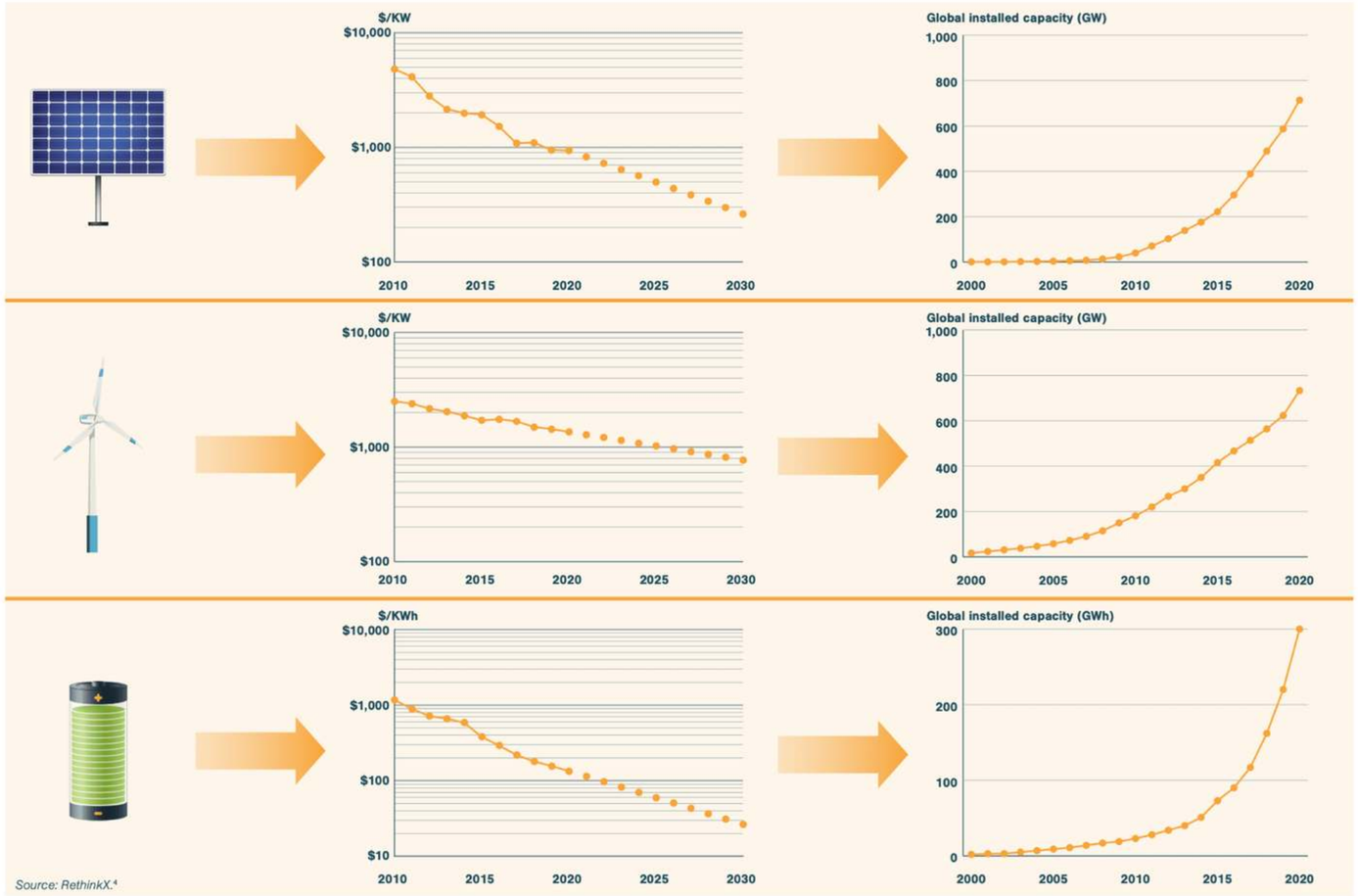
While the progress of science is predictable, the end result still feels like magic





Tesla FSD using camera only (no LiDAR)
Source: Tesla

Multiple exponential curves in action for energy



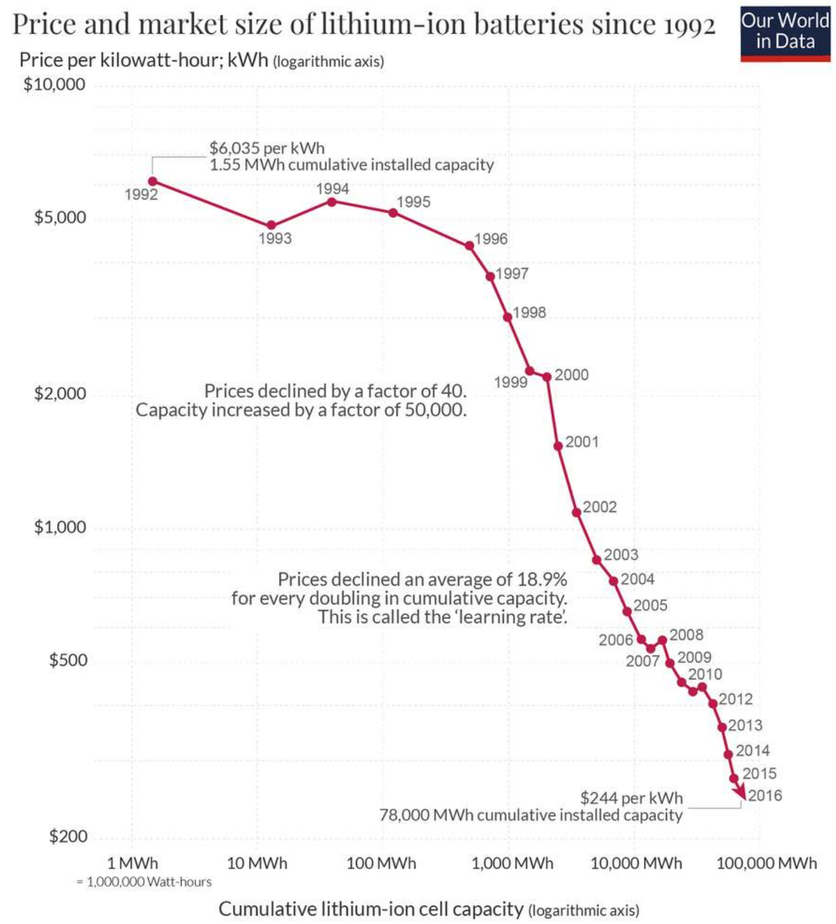
Source: RethinkX

Since 2010:

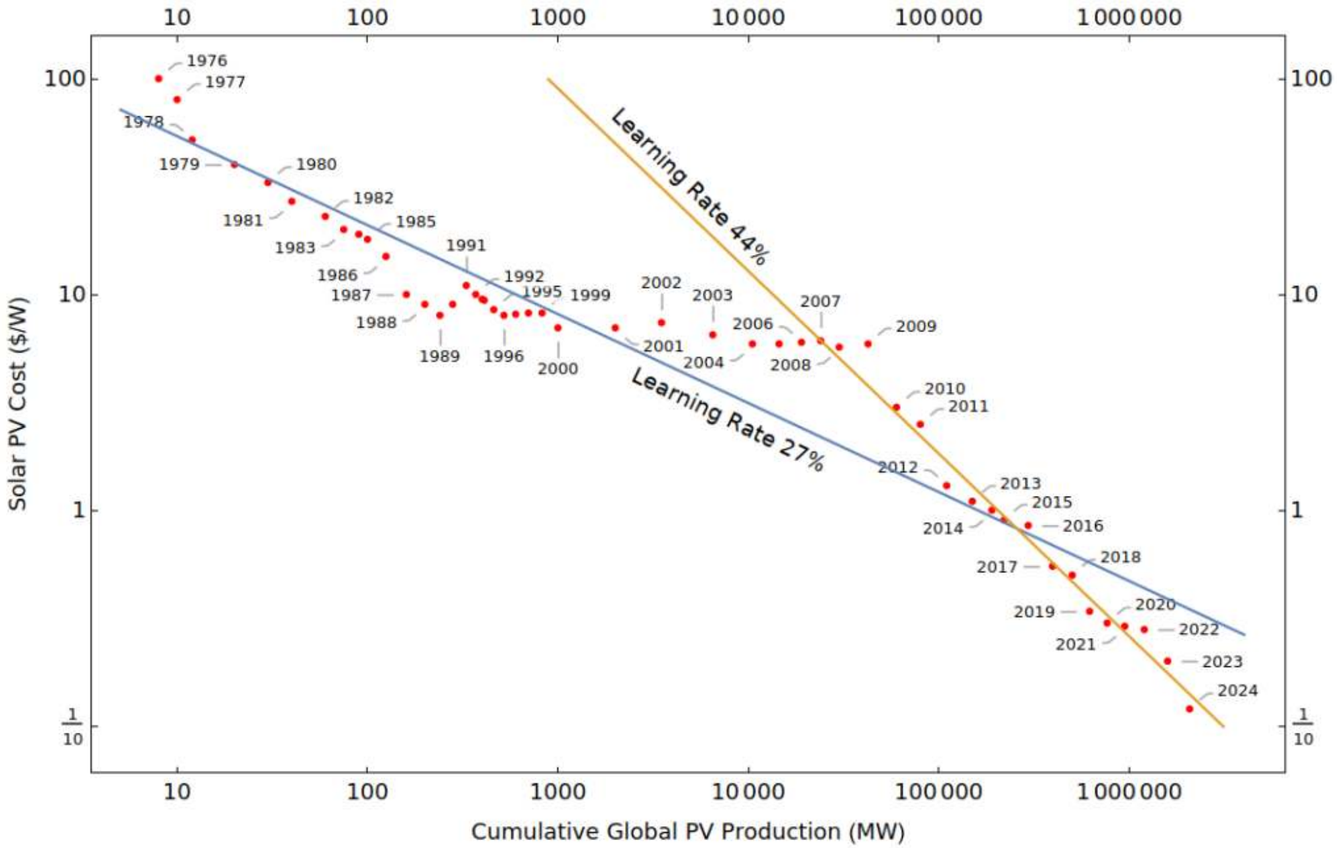
- costs for solar PV have fallen over 80%,
- more than 45% for onshore wind power
- almost 90% for lithium-ion batteries.

The cost declines are driving exponential growth.

Multiple technologies hit the ‘knee of the curve’ in mid 2000s with learning rates accelerating

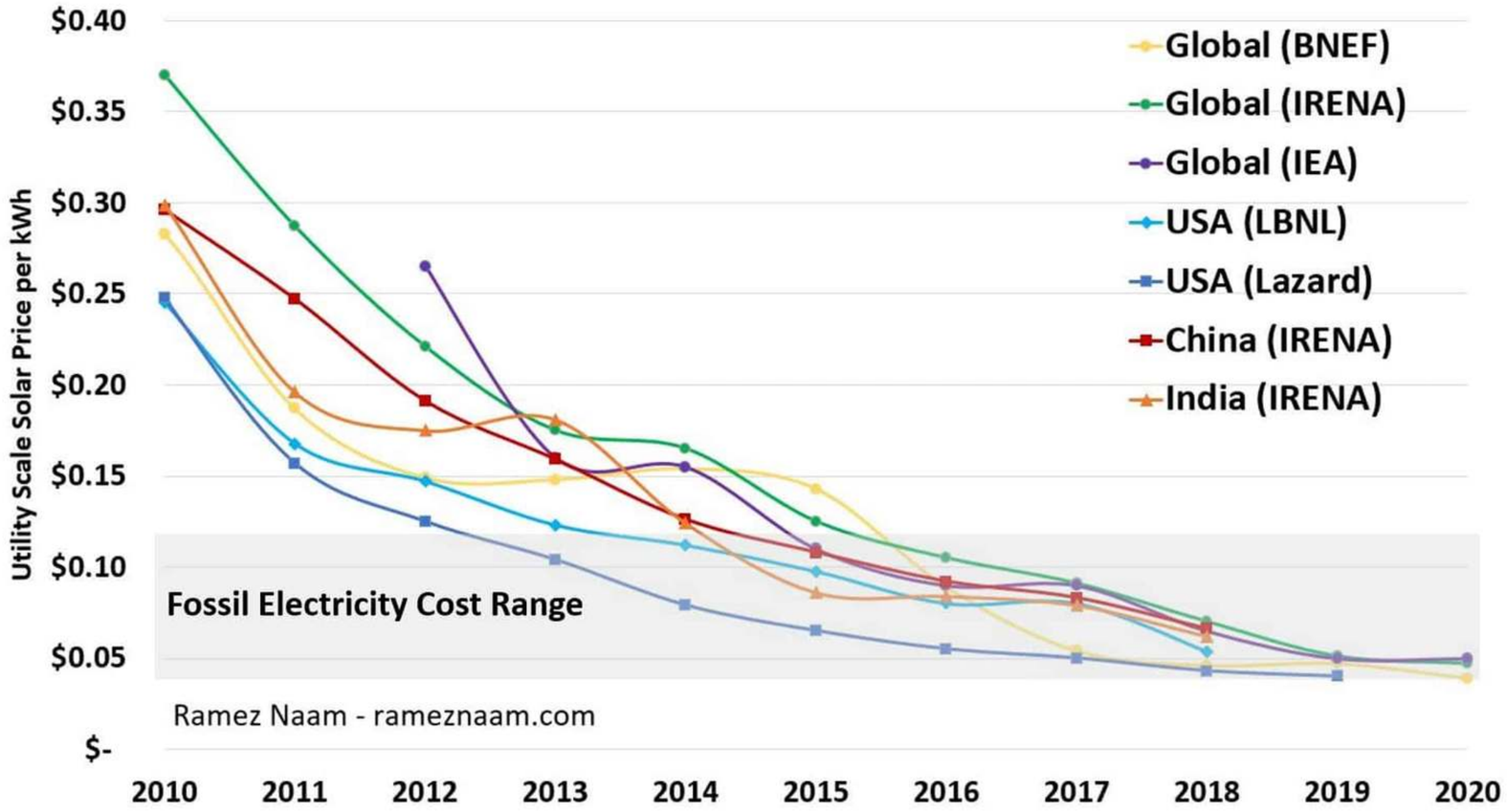


Learning rate of solar PV production



Source: Casey Handmer

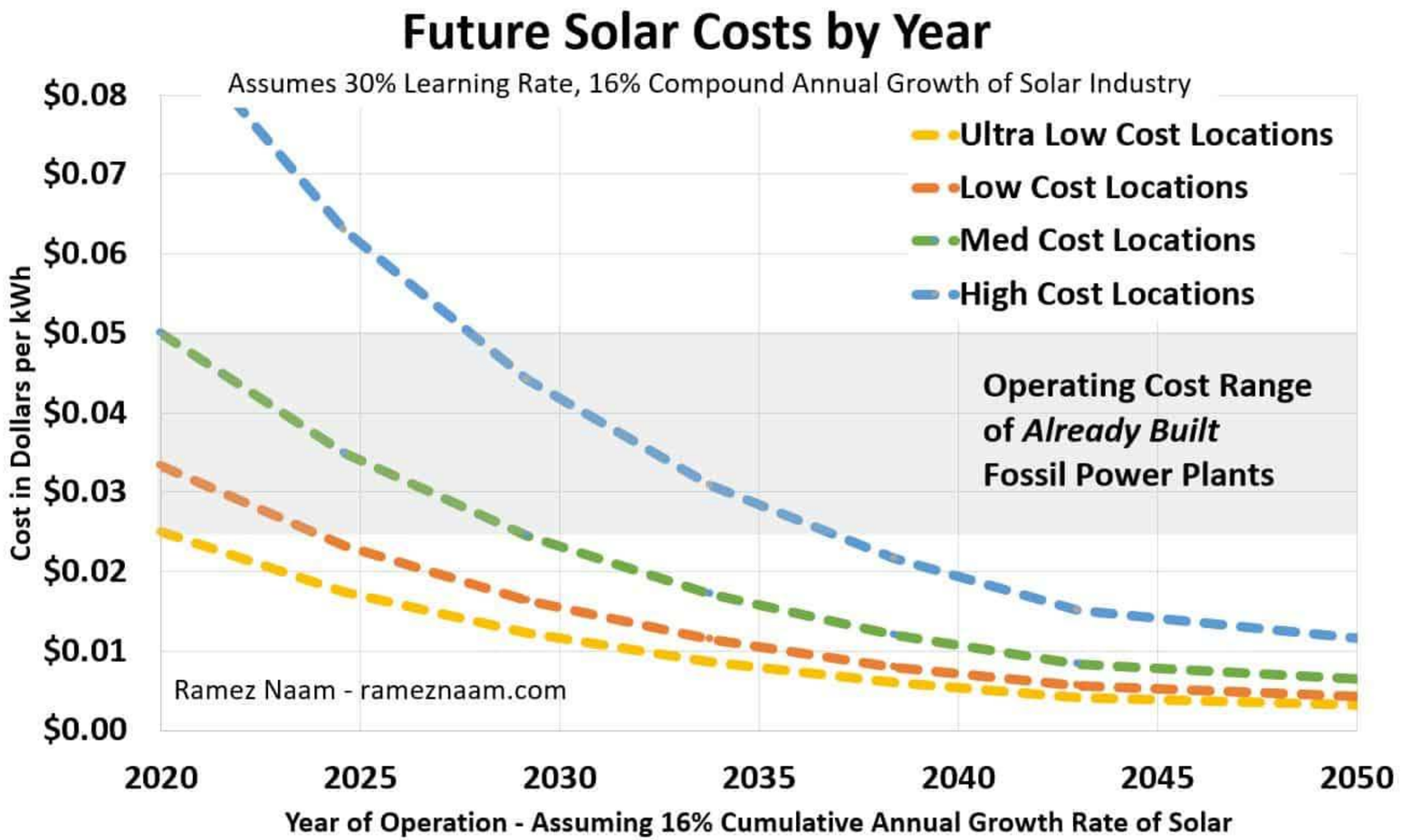
The actual unsubsidized cost of electricity from utility-scale solar projects has dropped by a factor of 5 - 8 in the years from 2010 to 2020.



Source: Ramez Naam

The gray shaded area of the chart shows the cost of electricity from fossil fuels (primarily coal and natural gas), we can see that building new solar plants started to become competitive on raw cost in the middle of this past decade, and is increasingly looking cheaper than building new fossil power plants.
Noting intermittency issues.

At a 30-40% learning rate, the cost of solar PV inevitably continues to decline below the operating cost of coal or gas power plants

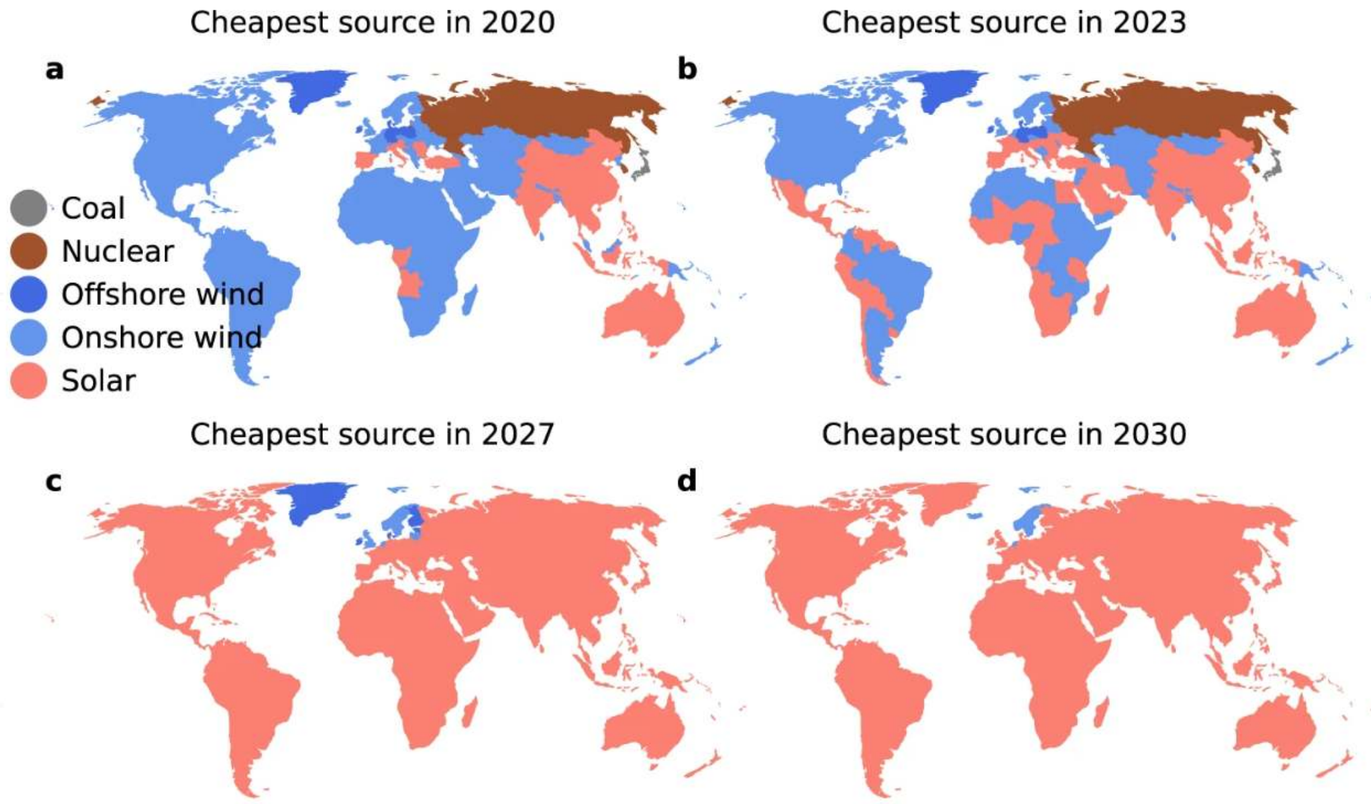


Source: Ramez Naam

This is what Ramez Naam called the third phase of clean energy, where building new clean energy is cheaper than keeping fossil fuel plants running.

This means the operating costs of even a brand new coal or gas power plant are higher than the construction *and* operating costs of a new solar plant.

If it keeps dropping at this pace, solar could well be the cheapest electricity over the vast majority of areas where people live.



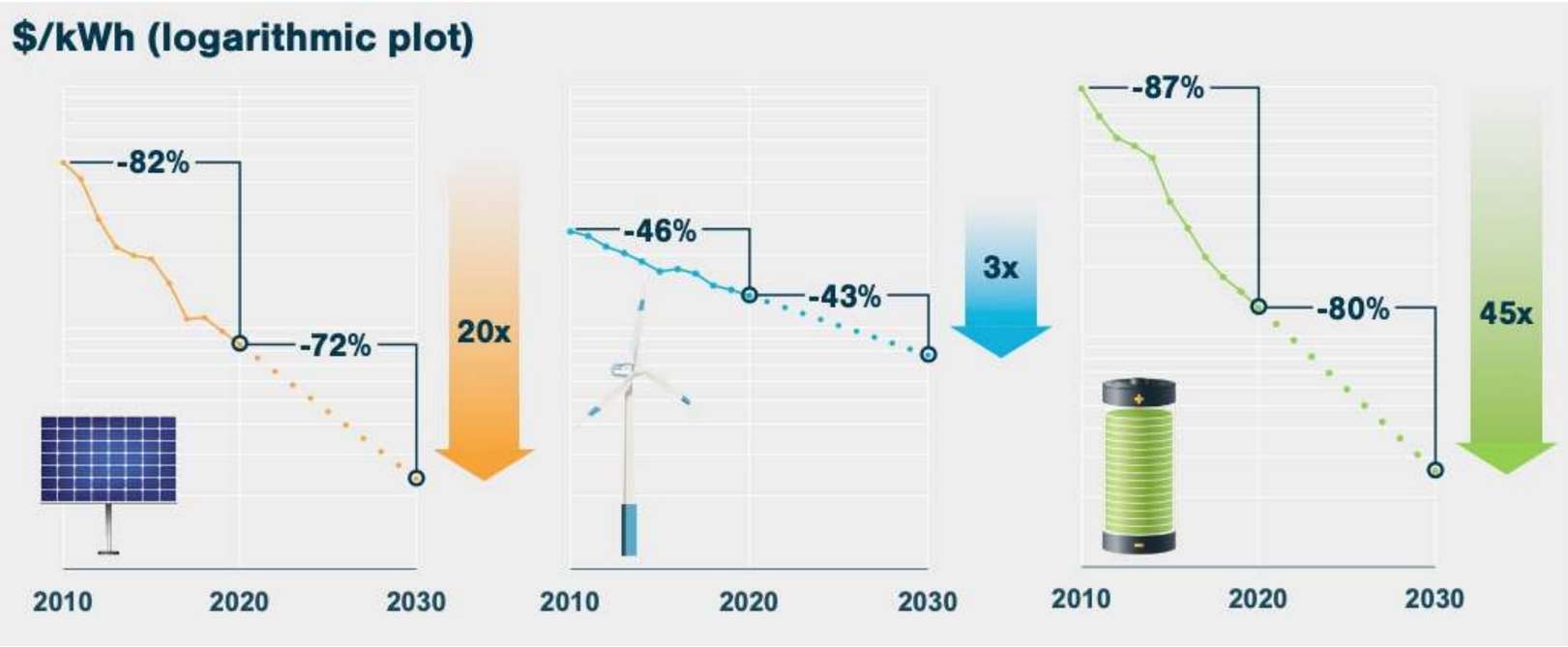
Each map shows the 70 E3ME regions: in 2020 (**a**), 2023 (**b**), 2027 (**c**) and 2030 (**d**). The biggest shift occurs between 2020 and 2027, which sees a range of technologies give way to solar PV as the cheapest source of electricity.

In a purely open market, these incredibly low prices would drive the world's remaining coal plants into bankruptcy, and steal some of the most profitable operating hours even from cheap natural gas plants.

Ramez predicts Renewables will start to encounter headwinds of their own making when solar makes up >20-30% of electricity (2% today) and when wind makes up >40-50% of electricity (6% today).

Source: Oct 2023 Nature Communications

No ‘Hail Mary’ required; the technology already exists with predictable declines in cost



Falling costs drive technology disruptions. Solar and wind are already the cheapest new generation options, and cost less than existing coal, gas, and nuclear power plants in many areas.

The cost of SWB systems will fall another 70% by 2030, making disruption inevitable.

Source: RethinkX

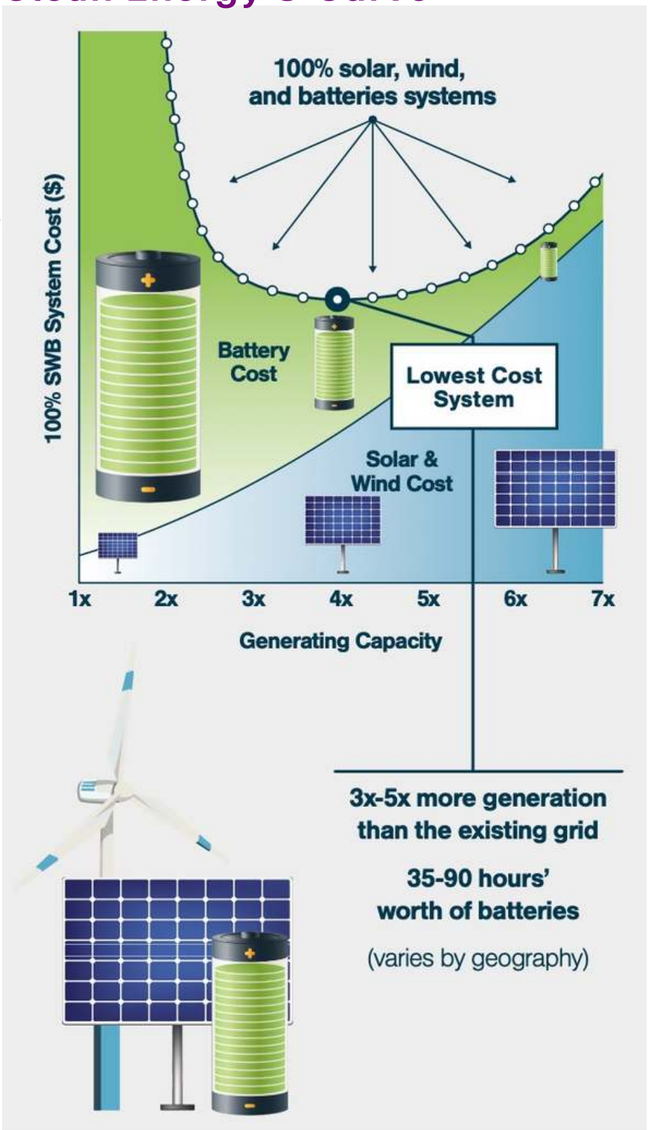
Solar-wind-battery (SWB) systems resolves the intermittency issues of solar and wind generation

Policymakers and investorsare under the false impression that solar PV and wind power cannot supply 100% of electricity without weeks' worth of battery energy storage.

Accounting for the true learning rate of SWB technologies means 100% SWB systems will be much cheaper than current forecasts.

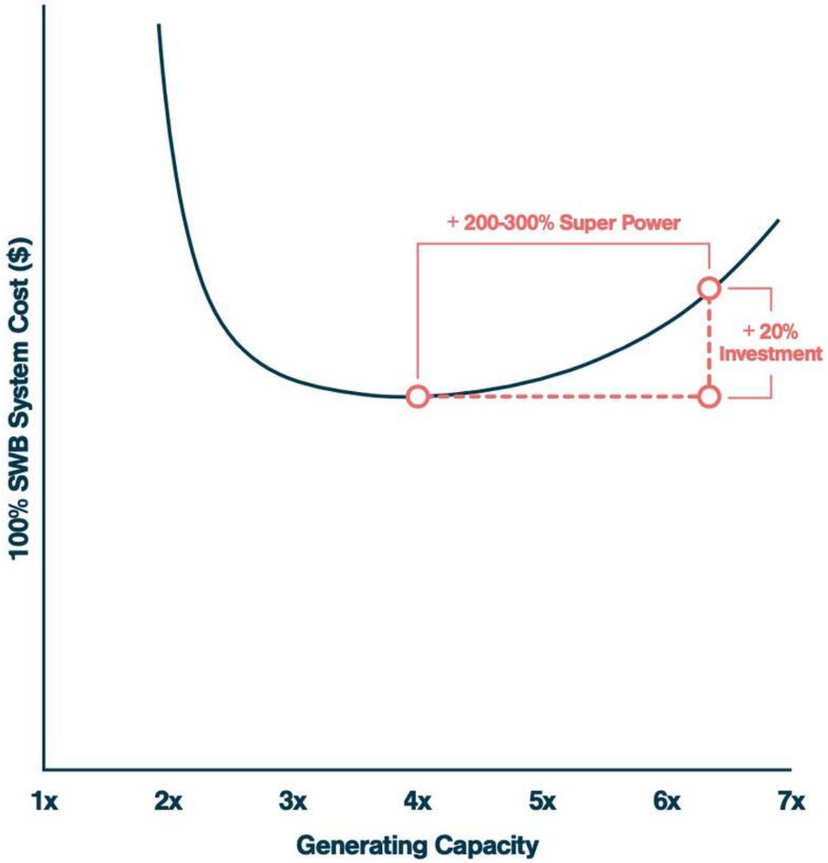
It is cost-effective to construct very large quantities of solar and wind capacity because that over-build generation capacity offsets energy storage requirements. Generation capacity around 3-5x demand and up to 90 hours of battery storage is the sweet spot for 100% SWB systems.

Clean Energy U-Curve



Source: RethinkX

100% SWB systems naturally produce a huge surplus of clean energy at near-zero marginal cost, even in areas with poor sun and wind resources



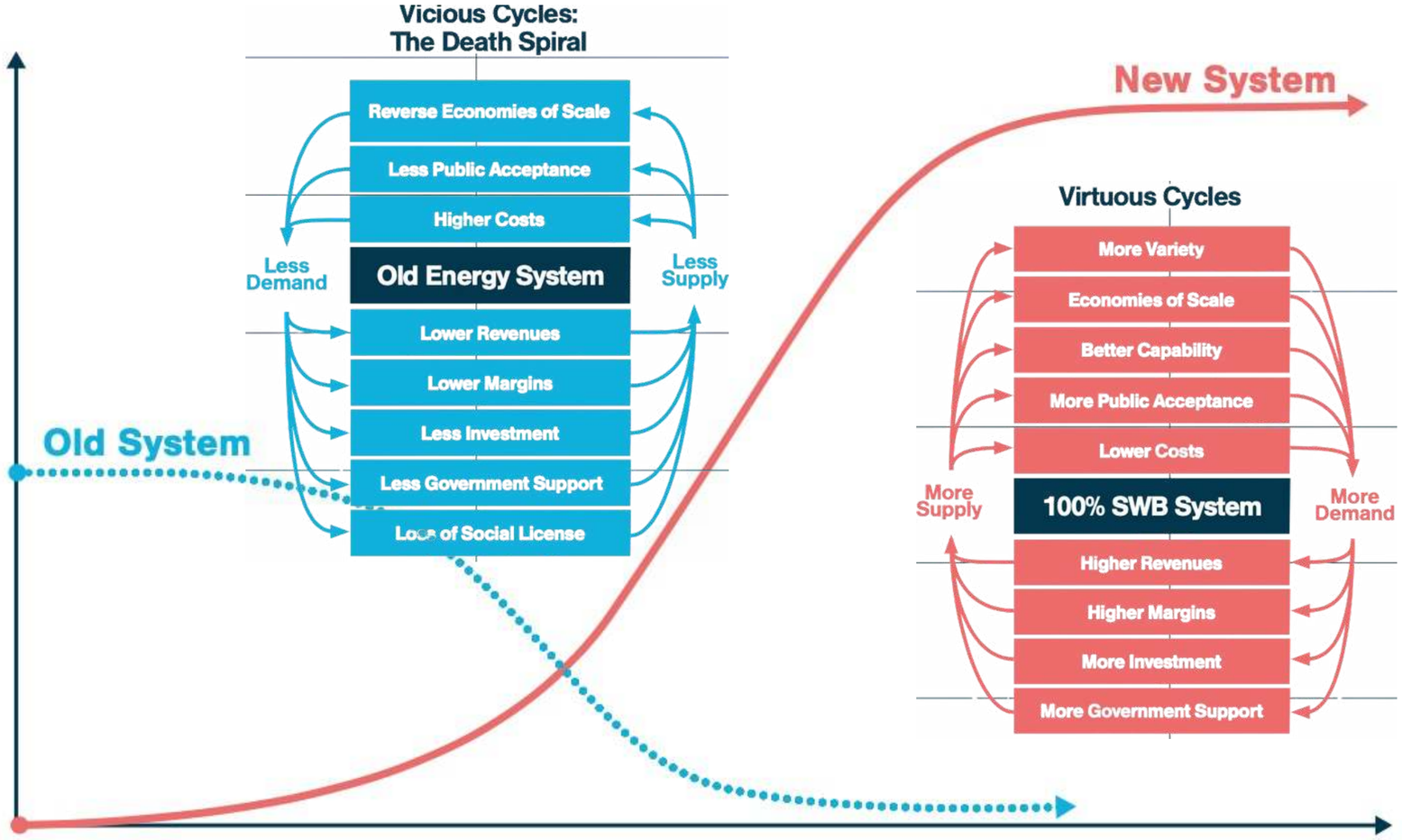
Source: RethinkX

Additional investments in generation yield disproportionately large returns of near-zero marginal cost electricity.

Even in regions with poor sunshine and wind resources, near-zero marginal cost power is available for some hours of the day on the majority days throughout the year - 64% of all days of the year in New England, on 93% of all days in California.

This surplus will create new opportunities for energy intensive industry with clean energy at low cost most days of the year.

Now capitalism will take over with feedback loops that make the transition inevitable

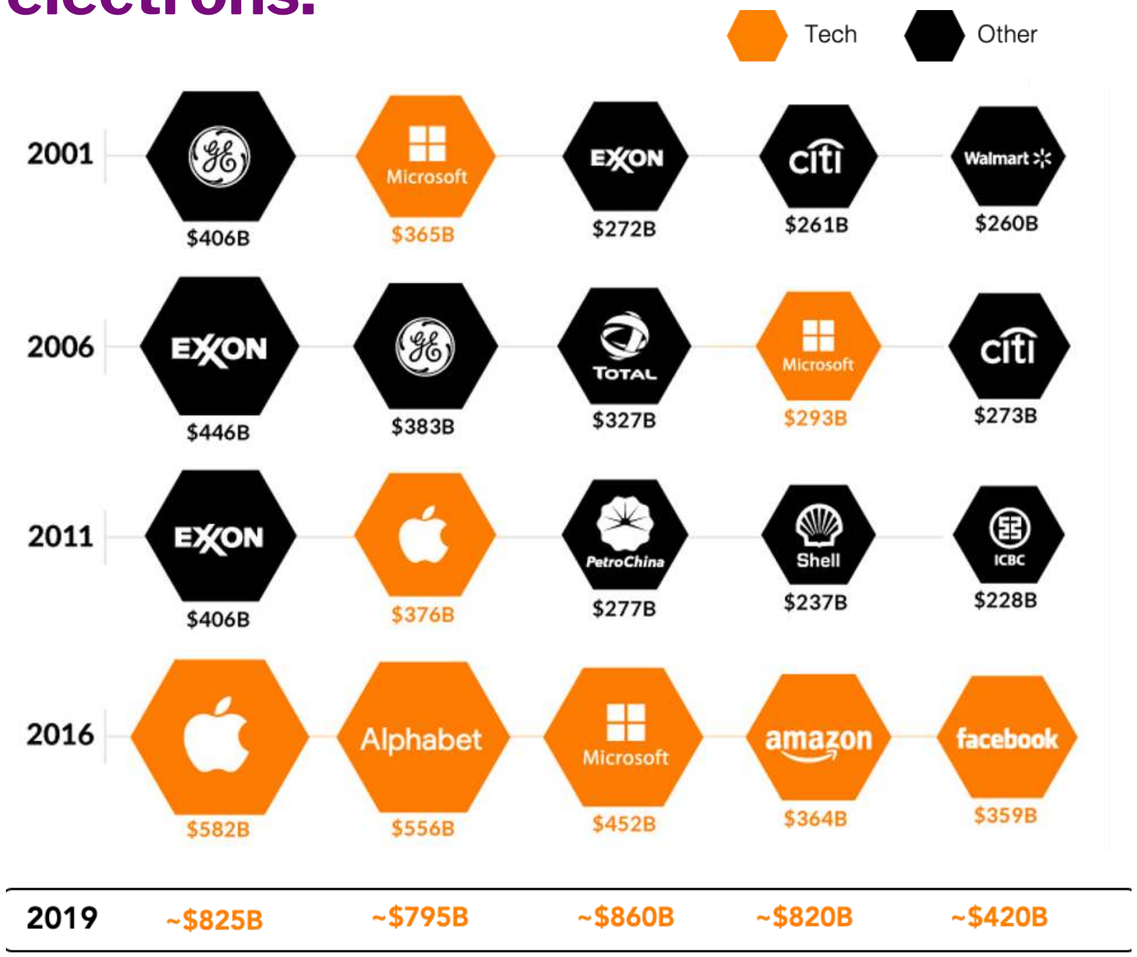


As with many previous disruptions throughout history, the new energy system that emerges will have a very different architecture that follows different rules and must be understood with different metrics.

In this case, the new system will be based on near-zero marginal cost energy from sunshine and wind instead of high marginal cost energy from fuels.

Source: RethinkX

What happened to the world of bits is now poised to happen to the world of electrons.



Source: The Exponential Agency

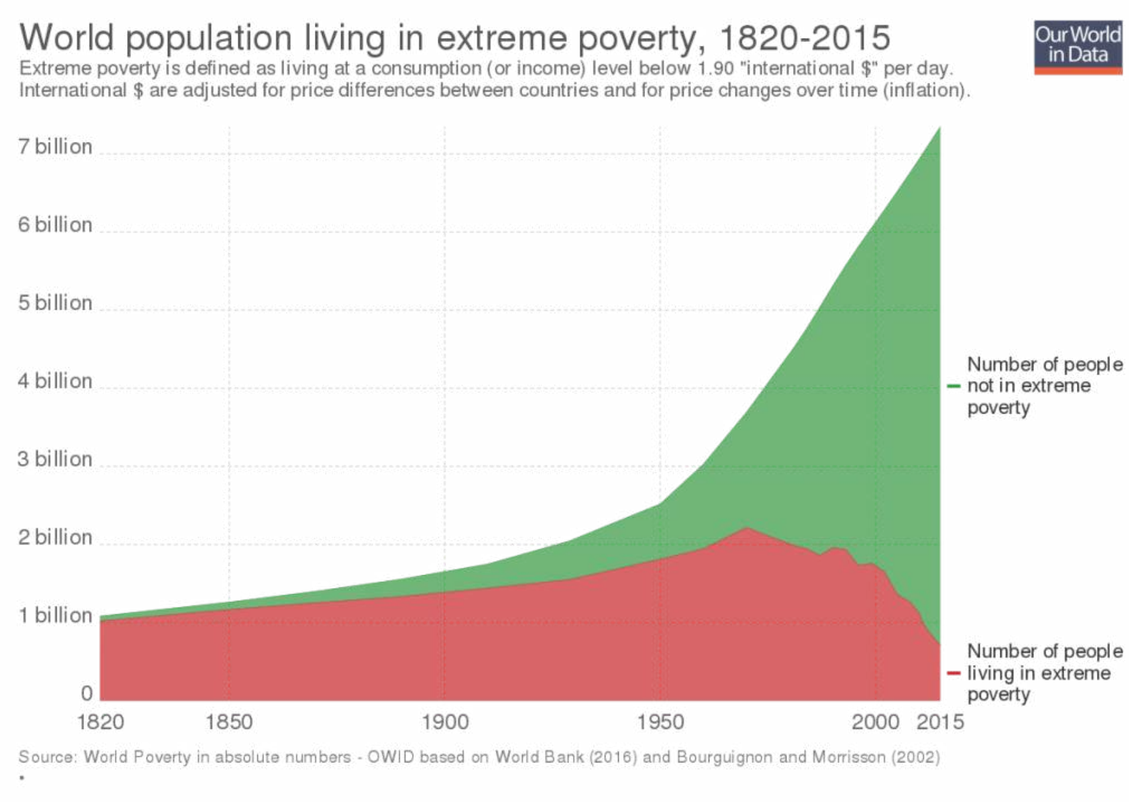
The shift from high marginal cost to near-zero marginal cost is a profound one whose consequences we have seen before in the information sector with computers and the Internet wiping out incumbent industries.

These old industries were replaced by a much larger information economy that operates on entirely different principles and supports new business models that were difficult to imagine prior to the disruption.

PART II: CLEAN ABUNDANT ENERGY UNLOCKS HUMAN PROSPERITY

1. Growing per capita energy use pulled humanity out of poverty
2. Avoiding Jovens paradox - more energy use does not mean more atmospheric CO2
3. Sidebar: The problems with degrowth
4. New opportunities with trillions of dollars of value creation potential
5. Technologies that use abundant clean electricity to abate emissions are ready to scale
6. How to position yourself to benefit? Build with an abundance mindset

Growing per capita energy use pulled humanity out of poverty



This unprecedented improvement in the human condition has been unlocked by social and political innovation, and underwritten by the consumption of copious quantities of cheap energy, almost all of it from fossil coal, oil, and gas.

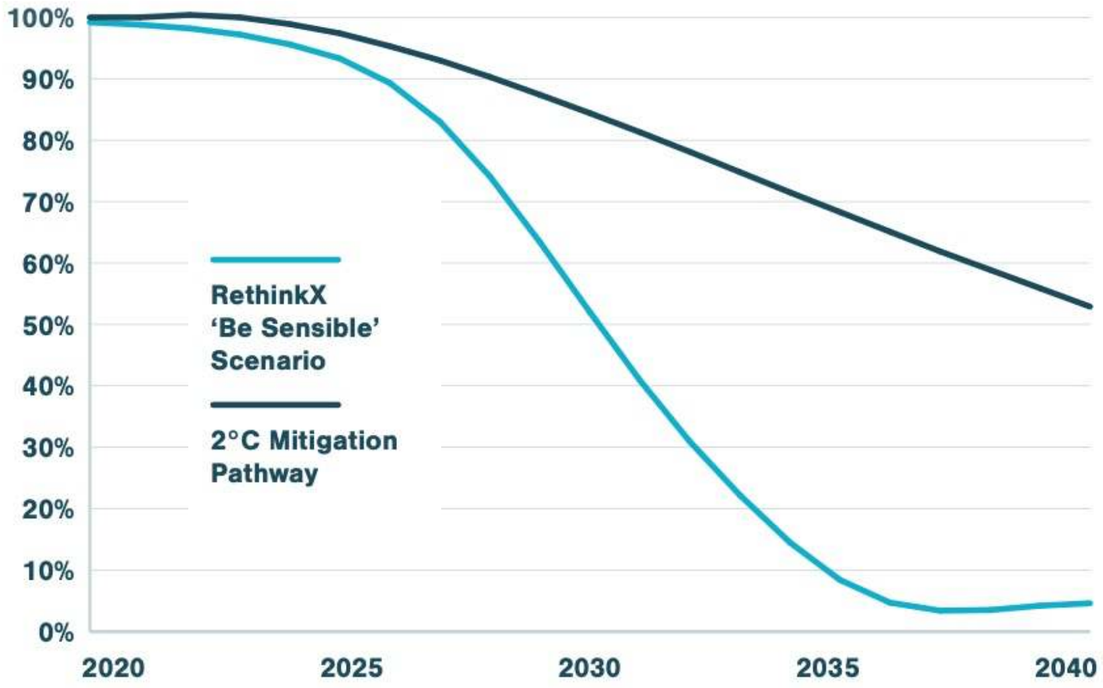
To a good approximation, oil has been the antidote to poverty.

Oil was just the cheapest form of useful energy. As we have seen, that is changing quickly in favour of solar-wind-battery systems.

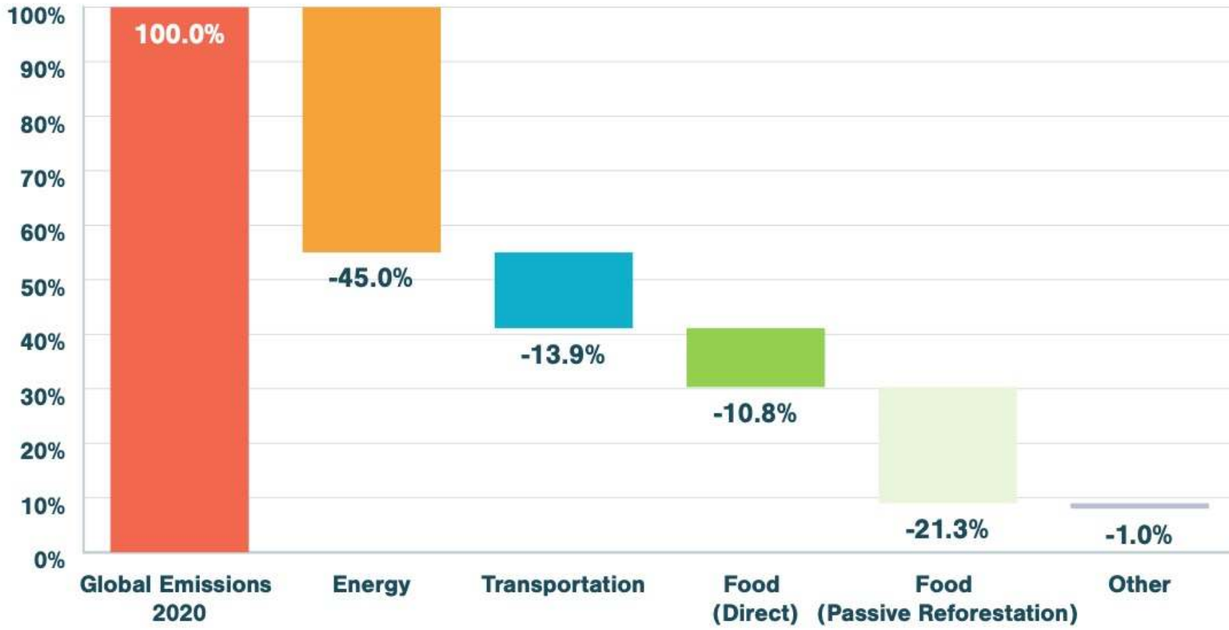
Source: Our world in data; Casey Handmer

Avoiding Jovens paradox - more energy use does not mean more atmospheric greenhouse gases

GHG Emissions forecast by RethinkX vs the IPCC 2C Mitigation Pathway. Scenario assumes market-driven adoption of SWB systems



Emissions Mitigation and Offset by 2035 by Sector in the RethinkX 'Be Sensible' Scenario



Source: RethinkX.

Sources: IPCC, Our World in Data, Global Carbon Project, RethinkX.[12,13,14,15]

Sidebar: The problems with degrowth

The default climate discourse in recent years has been congruent to an acceptance that curtailing CO2 emissions would require the regrettable but ultimately impersonal de-industrialization and re-impoverishment of most of the world.

Our controversial position is: We shouldn't do this.

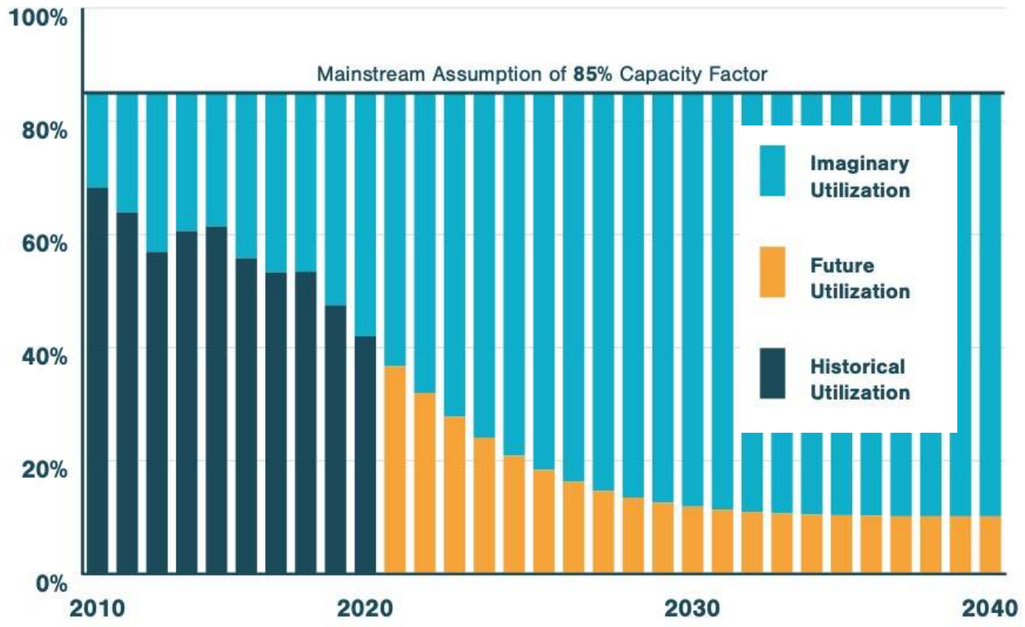
Many social and environmental problems can be solved with more (not less) cleaner, cheaper energy.

Degrowth is a failing movement:

- Ezra Klein pointed out that major reductions in living standards would be politically unacceptable in rich countries.
- Branko Milanovic showed that meaningful global degrowth would have to go beyond rich countries; it would have to stop poor countries from escaping poverty, which would be both politically untenable and morally wrong.
- Kelsey Piper noted that coordinated global degrowth would take much more economic central planning than we're actually able to do.

Traditional energy industry will not fade quietly away, there is too much (over-priced) value at stake

U.S. Coal Capacity Factor – 85% Assumption that drives new power plant business cases vs. Reality



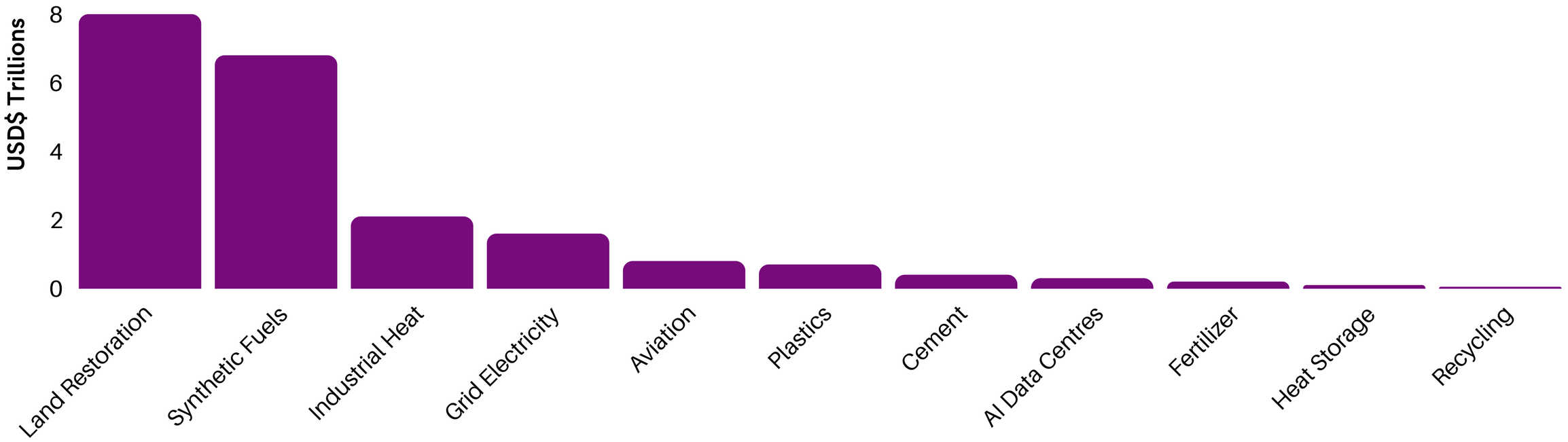
RethinkX: Rethinking Energy LCOE

- New coal, gas and nuclear facilities are using heroic capacity assumptions to make their business cases stack up (1).
- Over USD$2.2 trillion has been invested in fossil and nuclear energy in the electric power sector worldwide since 2010.
- Conventional energy assets are severely mispriced, and their overvaluation is creating a growing asset valuation bubble

(1) This assumption has been false for at least ten years. The rates at which conventional power plants are utilized will continue to decrease as competitive pressure from near-zero marginal cost solar photovoltaic and onshore wind power, and battery energy storage continue to grow exponentially worldwide.

Near-zero marginal cost energy supply will create many trillion dollar opportunities as old ways of doing things become untenable

Market size of sectors that are unlocked by energy abundance



Source: Casey Handmer; TEA Analysis

Ideas that become viable as solar and battery costs continue to inevitably decline have already been proven and are ready to scale

Terraform Industries converts electricity and air into **synthetic natural gas**. Producing green hydrogen at <$2.50/kg-H2 and Direct Air Capture CO2 at <$250/T-CO2.

Antora is unlocking zero-emissions **industrial heat** (33% of global CO2 emissions), cheaper than fossil fuels. Uses solar electricity to heat blocks of solid carbon to 2000C and deliver energy at the scale and temperatures that large industrial operations demand.

Brimstone makes **carbon-negative cement** that actually removes carbon from the air during it's manufacturing process. Cement production accounts for 8% of global carbon emissions.

Nitricity uses renewable energy to make high-quality, fast-acting, plant-based **fertilizer** free of greenhouse gases. Nitrogen fertilizer is responsible for up to 7% of all global GHG emissions.

Twelve produces **jet fuel** made from CO2, water and renewable energy and has up to 90% lower emissions than conventional jet fuel (2.5% of global GHG emissions).

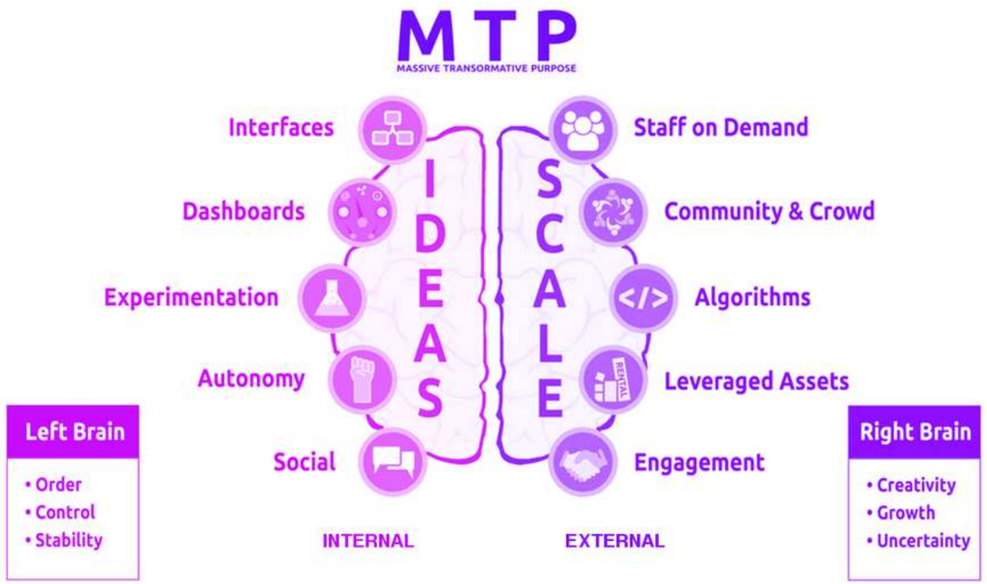
Lanzatech has developed processes that recycles emissions from manufacturing processes into **synthetic plastics**. Imagine when your shampoo bottle started life as emissions from a steel mill.

How to position yourself to benefit? Build an Abundance Mindset...

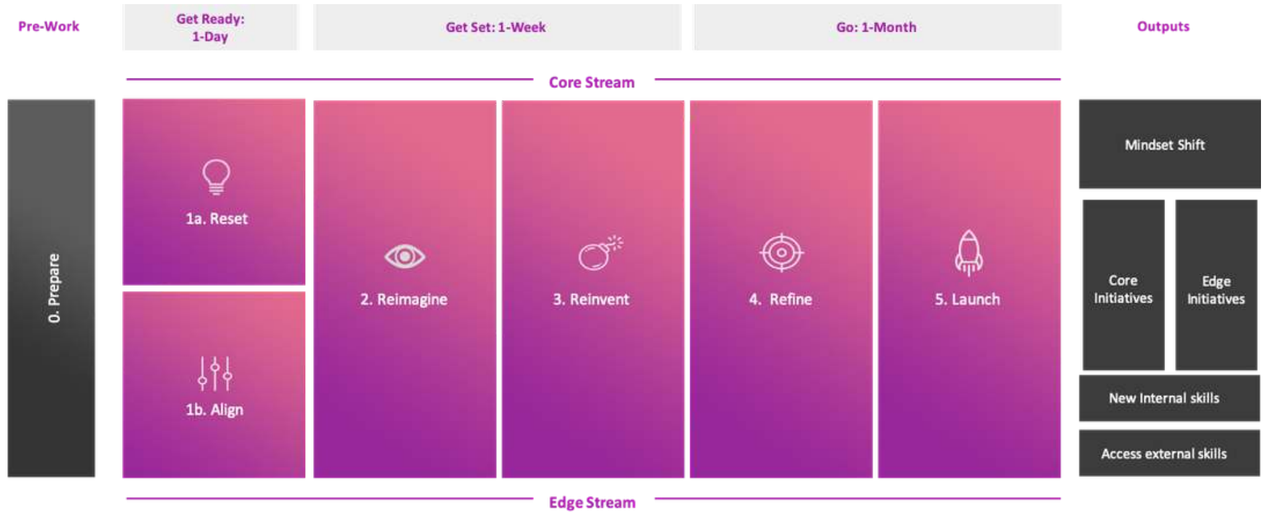
1.Information Accelerates Everything	Regular doubling performance vs cost | Moore's Law
2. Drive to Demonetization	Marginal cost of supply trends to zero | Invites competition
3. Disruption is the New Norm	Stability is gone | Linear is gone | Volatility is gone
4. Beware the Expert	Experts caught in linear thinking | HiPPO vs Geeks
5. Death to the 5 Year Plan	Purpose trumps strategy | Execution overrides planning
6. Smaller Beats Bigger	Adaptability and agility trump economies of scale and scope
7. Rent, Don't Own	Leverage others assets and people
8. Trust Beats Control, Open Beats Closed	Progress comes from trust and transparency
9. Everything is Measurable and Knowable	The power of data and dashboards

...and transform your business model to profit from abundance

ExO Business Model Attributes



Rapid Transformation Process



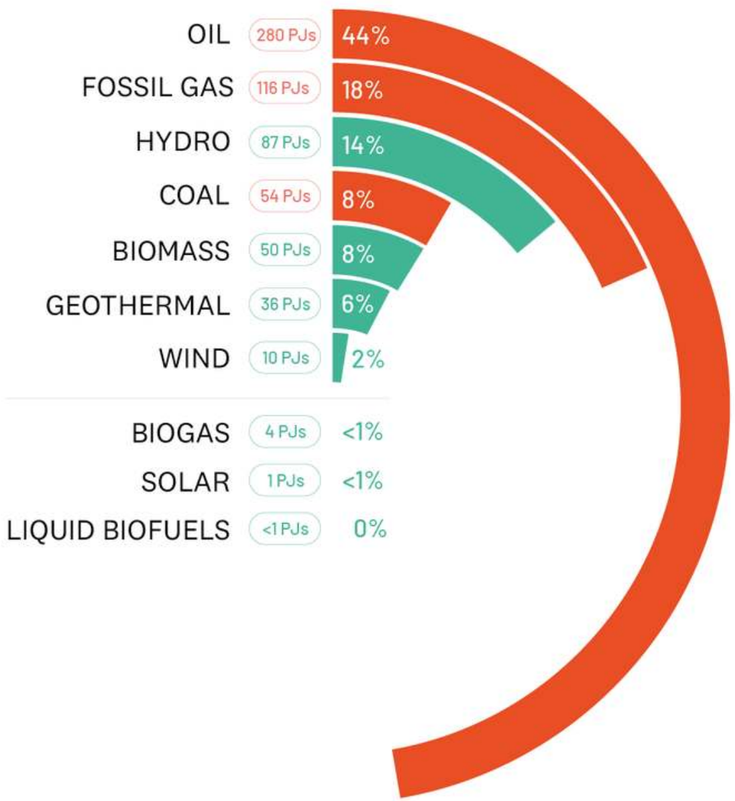
We have helped many organisations accelerate their transformation by three years in 10 weeks or less using this approach.

PART III: NEW ZEALAND CONTEXT

1. NZ is very well positioned to lead the world in this transition if it wants to
2. $700M investment in battery storage is all it would take to flatten winter peak demand, and the costs these peaks drive into the whole system
3. The market is ready to flip to clean energy on purely economic rationale, if it was functioning normally
4. There is significant upside potential to moving early
5. The plan to usher in clean abundant energy for NZ is very low cost, benefiting kiwis economically and environmentally

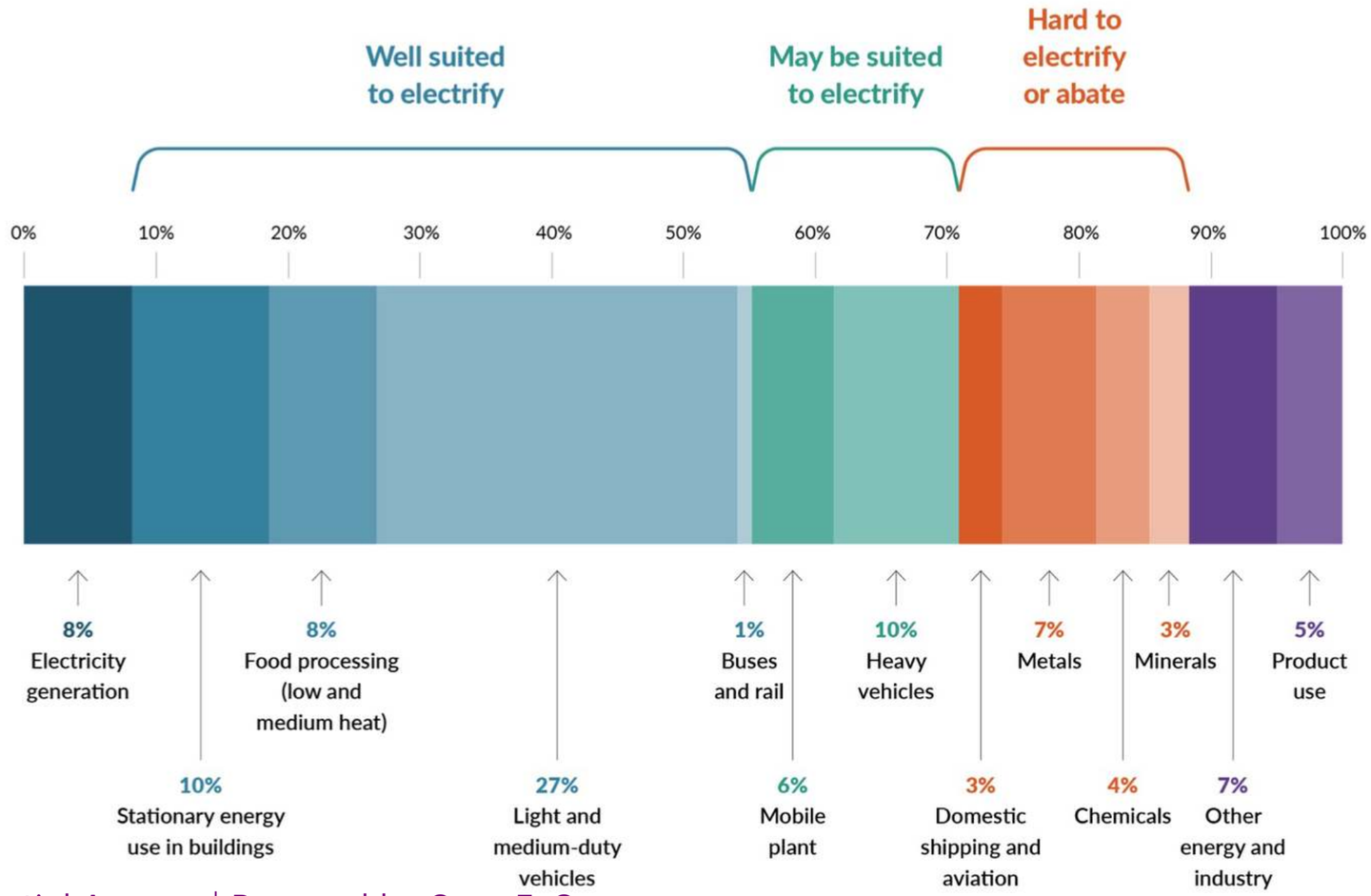
New Zealand's 40% renewable energy mix is already one of the highest in the world and 70% of demand suited to further electrification

Primary energy consumption in New Zealand



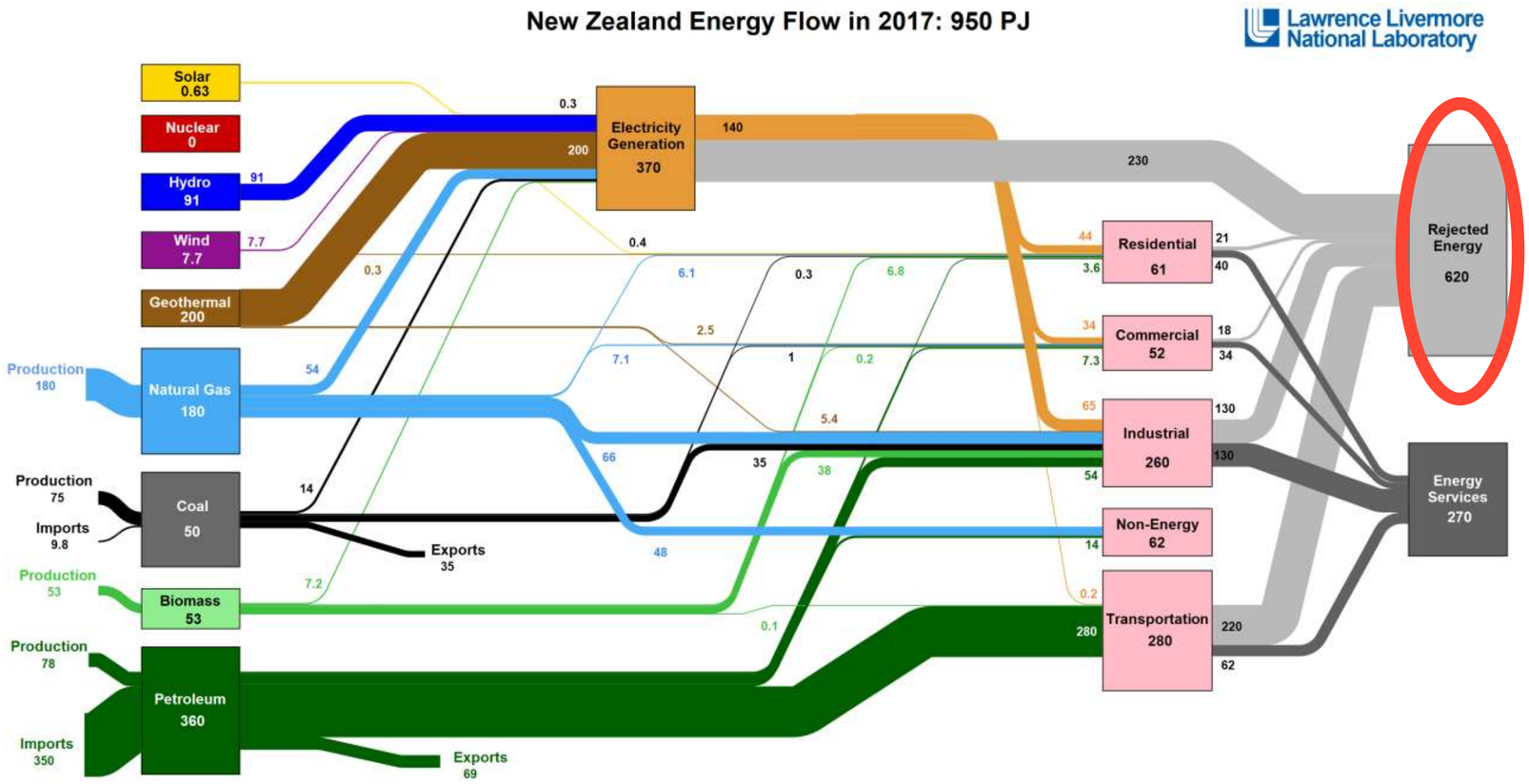
Source: EECA and MBIE

New Zealand's emissions from the energy sector and industrial processes, 2022



We need only one third of the input energy we currently use to satisfy current demand because the new system reduces waste

Sankey Diagram of NZ Total Energy Flow, 2017

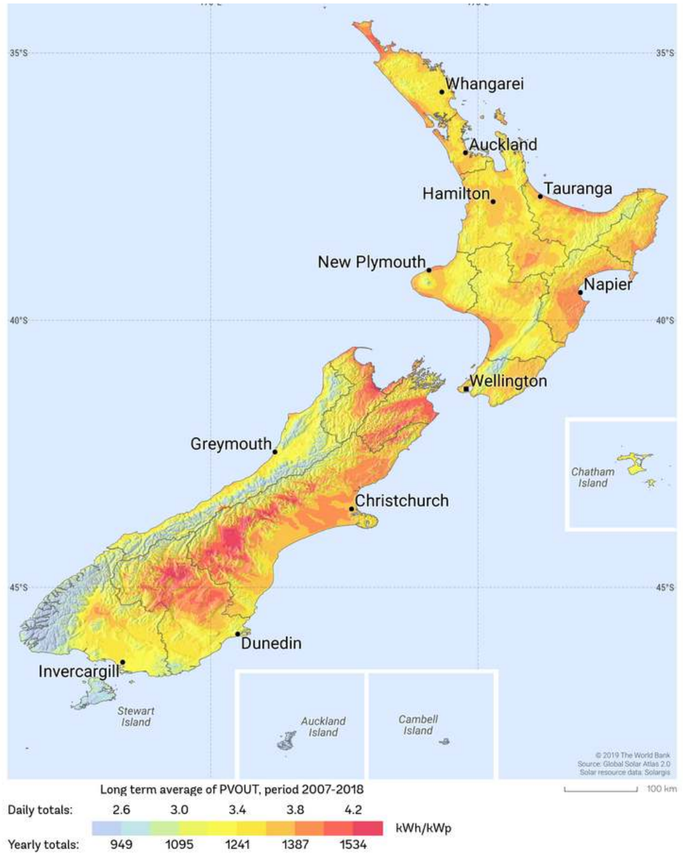


- 2/3 of our energy is wasted!
- Renewable generation and electrifying transport reduces 2/3 of this waste.
- Industrial heat is the last ‘big rock’ to electrify
- These changes are inevitable
- We will only need 1/3 of the input energy we currently need to produce the same active work.

Source: LLNI based on IEA data 2021

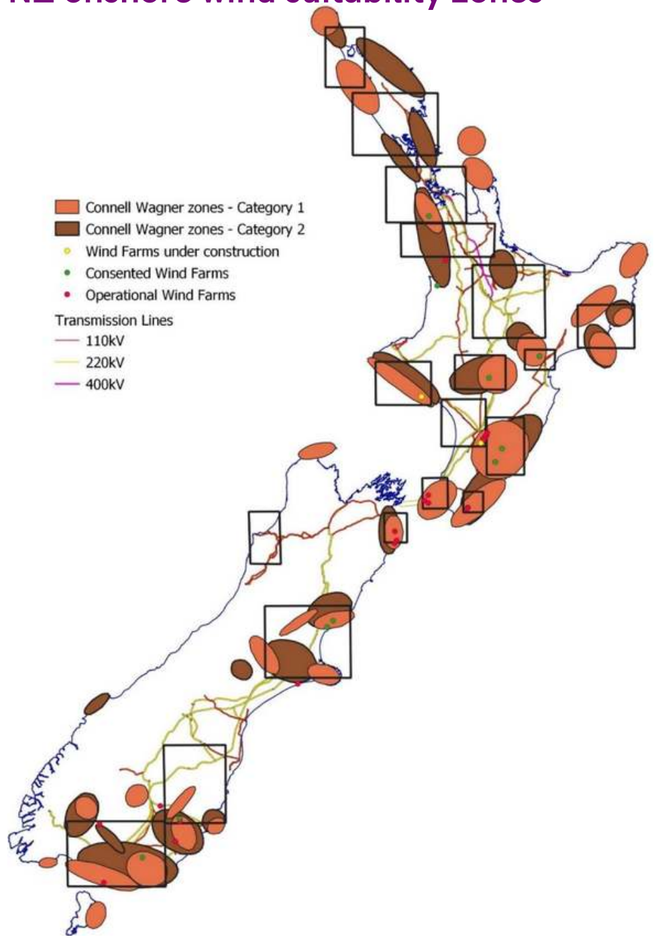
New Zealand is well endowed with natural resources for solar and wind energy

NZ PV Power Potential



Source: SolarGIS; MBIE Roaring40s

NZ onshore wind suitability zones

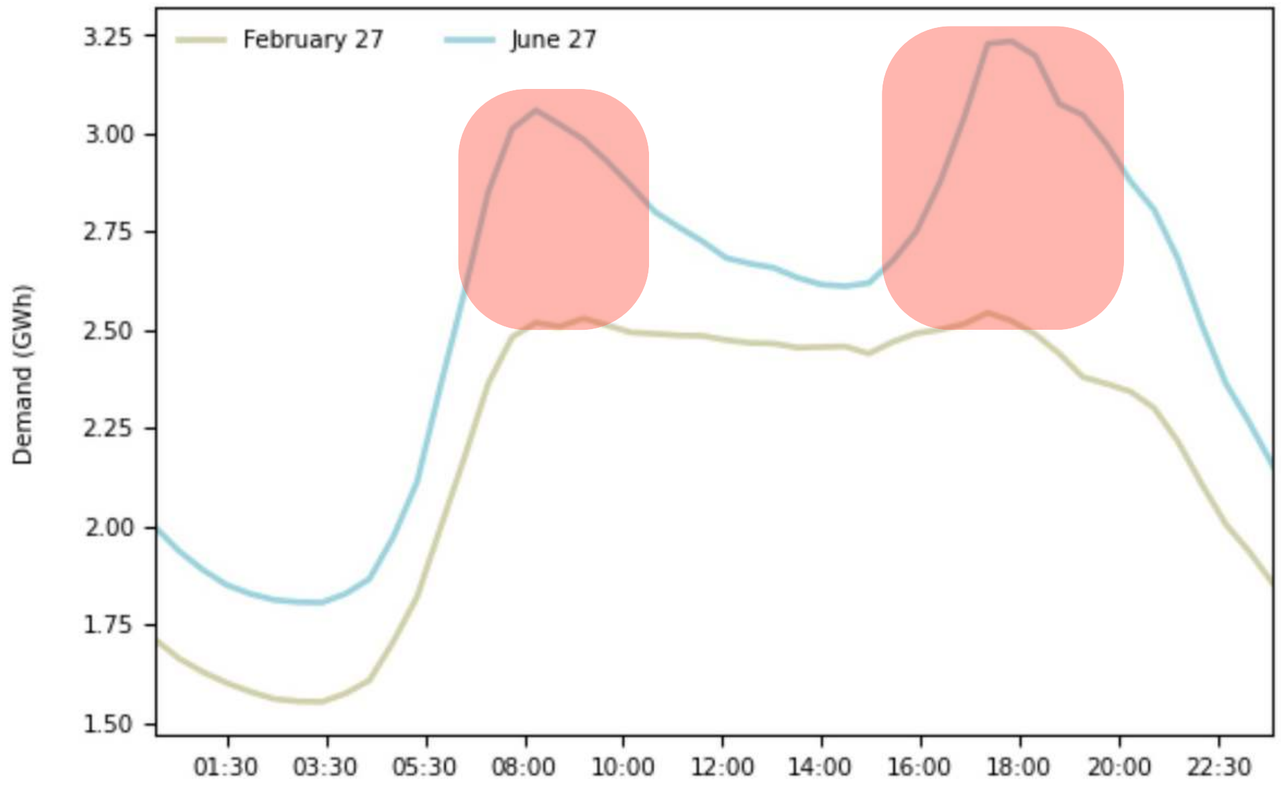


Most areas of New Zealand get more sunshine energy per year than Germany does, and Germany has one of the highest amounts of solar per capita in the world.

Onshore wind is so abundant in New Zealand that most analysts predict more growth in wind generation than solar for the next couple of decades.

Electricity demand is characterised by dual winter peaks requiring 3-4 hours of timeshifting capability to flatten the peaks that drive system cost

Average Daily Electricity Demand in NZ Winter vs Summer



Source: Electricity Authority

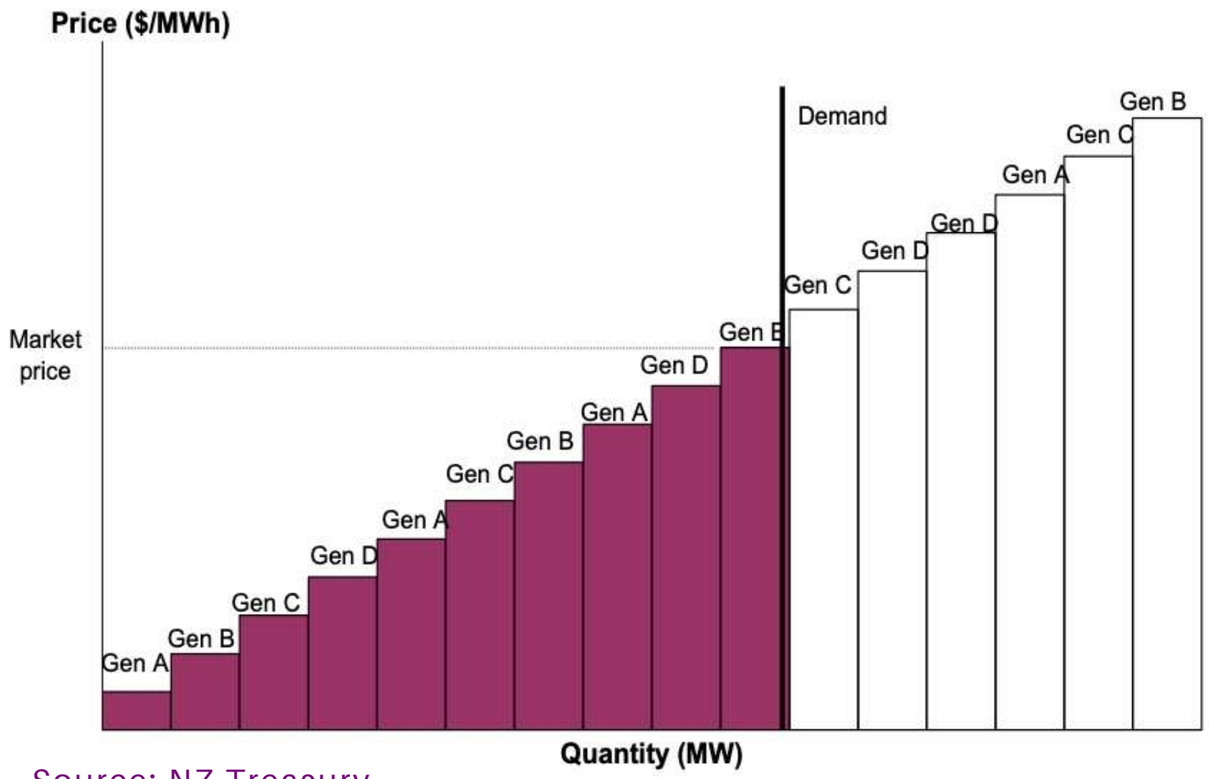
The electricity system is designed to balance generation and demand across the country with the most expensive times being 6-10am and 5-9pm during winters.

These peaks drive costs in generation, transmission and distribution.

Flattening the peaks will reduce total costs in the system.

Wholesale electricity prices are set by the marginal cost of supply leading to perverse incentives to constrain supply and elevate the cost

Determination of electricity market price under uniform pricing



Source: NZ Treasury

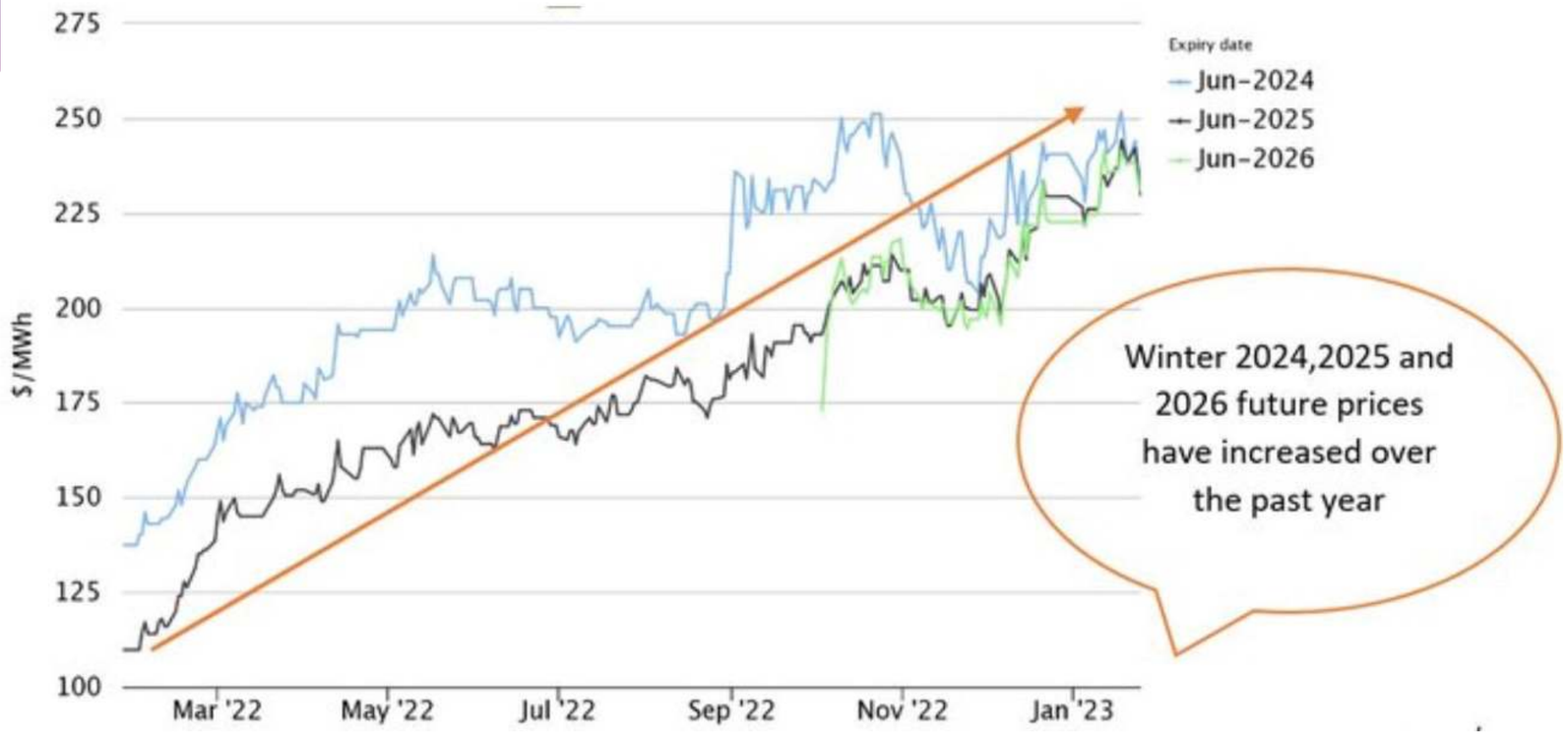
Wholesale electricity spot price approach is uniform pricing. In theory, if there is sufficient competition, this pricing mechanism should achieve a market price paid by consumers to reflect the marginal cost of electricity production, even when prices are highly volatile.

However, when competition is weaker in the market, generators may be more incentivised to drive prices above their marginal costs.

NZ market is characterised by 4 gen-tailers with 80% of the retail market and generate 90% of the electricity.

Normal well-functioning markets counter this incentive by new players arriving to arbitrage the opportunity

Winter 2024,2025,2026 future prices



Source: Electricity Authority

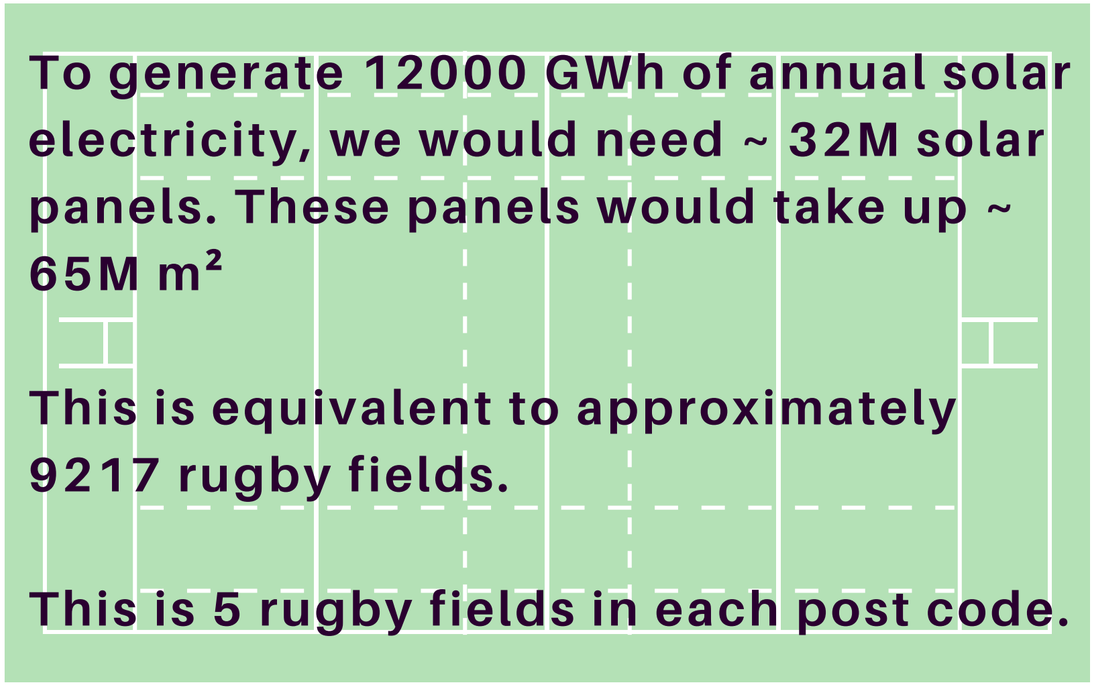
Electricity futures markets show winter prices are going to increase substantially.

Most of this due to supply challenges with low hydro lakes, no new gas generation, high coal prices and low new renewable capacity proposed.

At these prices, we should be seeing a rush of new generation projects.

12,000 GWh (equivalent of annual gas output) of SWB systems requires five rugby fields of solar panels in every NZ area code, not trivial but possible

How much solar is required to equal current gas generation



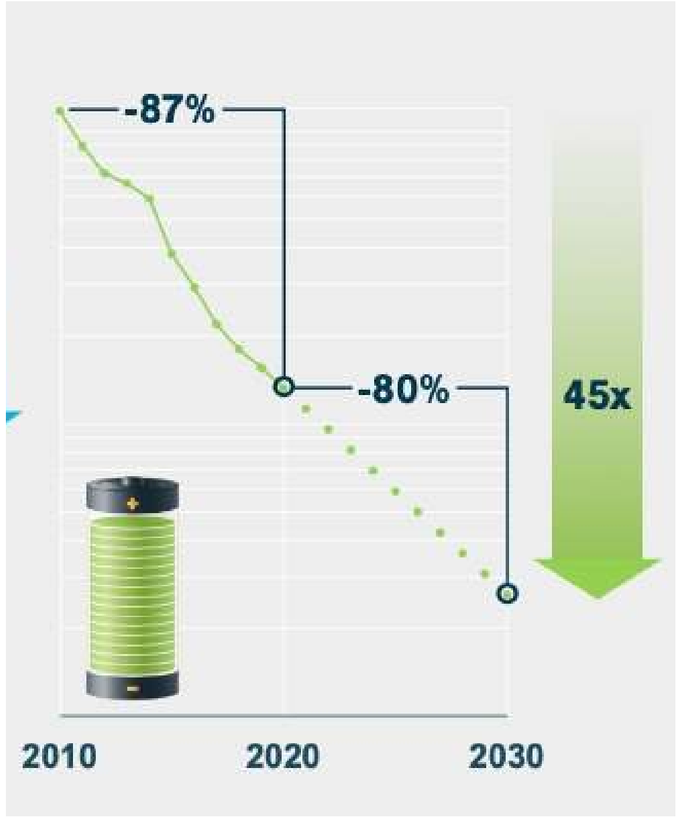
1. The average output of a solar panel is approximately 372 kWh per year.
2. The average size of a solar panel is about 2 m²
3. The size of a rugby field is approximately 7000 m²
4. The gas-fired electricity generation for 2024 is 4091GWh
5. There are 1856 post codes in NZ

The Clean Energy U Curve suggests that a SWB system with 3-5 times generation capacity and 35-90 hours of storage can not only replace conventional power sources, such as gas and coal plants, but **also produces excess energy at near-zero marginal costs for most days of the year.**

To make this real, we estimate five rugby fields of solar generation in each post code of NZ can replace the highly profitable gas-fired electricity used for peak winter periods.

About $250M investment in battery storage (residential and grid-batteries combined) is all it would take to flatten winter peak demand

RethinkX Battery cost forecast



Source: rethinkX; Hornsdale Power Reserve, TEA analysis

Winter peaks drive much of the cost of the whole system.

4 hours of storage can flatten winter peaks.

NZ winter peak usage is 1.5GWh more than summer peak. This much battery storage capacity at 2024 prices ($250/kWh) would be $375m and less than $190m by 2030.

Assuming a 5 year build timeline this is a roughly $250m cost to make electricity more affordable for kiwis year-round.

The arbitrage opportunity alone suggests a payback period of less than three years, as demonstrated by the Hornsdale Power Reserve in South Australia.

1- Hornsdale Power Reserve is a 194MWh costing AUD$172M between 2017 and 2020

Strategically placing storage can also offset some of the $6.4b that EDBs expect to spend up to 2030, saving all NZers through lower distribution cost

Case 1: Peak Load Management / Congestion Relief on a Feeder:
Traditional Solution: Reconductoring a section of an 11kV overhead line (e.g., 1-2 km) or upgrading a local distribution transformer (e.g., 300 kVA to 500 kVA).
Estimated Traditional Cost Range: NZD 100k - NZD 500k

A strategically sized BESS (e.g., 250kW/500kWh could become cost-competitive for deferring upgrades by 2026-2028.

Case 2: Deferral of a Small Zone Substation Transformer Upgrade:
Traditional Solution: Upgrade 5MVA transformer to a 10MVA unit.
Estimated Traditional Cost Range: NZD 500k - NZD 2m+ (includes transformer, switchgear, civil works, and control systems).

Larger BESS or significant aggregated V2G capacity could start to become viable for 1-3 year deferrals by 2028-2030.

We need to more than double renewable generation while electrifying transport and industrial heat to satisfy our demand for energy in 2050

Stated Ambition of the Government's Electrify NZ Strategy

Electrify NZ

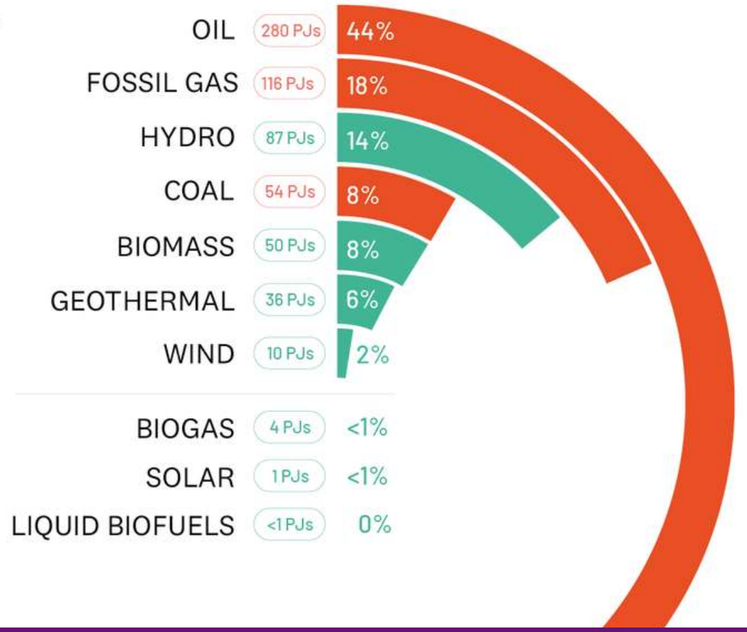
Te Kāwanatanga o Aotearoa
New Zealand Government

The Government has committed to **doubling renewable energy** by 2050.

We are making **consenting** faster and cheaper

We will also **remove barriers** that slow or prevent electrification

Primary energy consumption in New Zealand

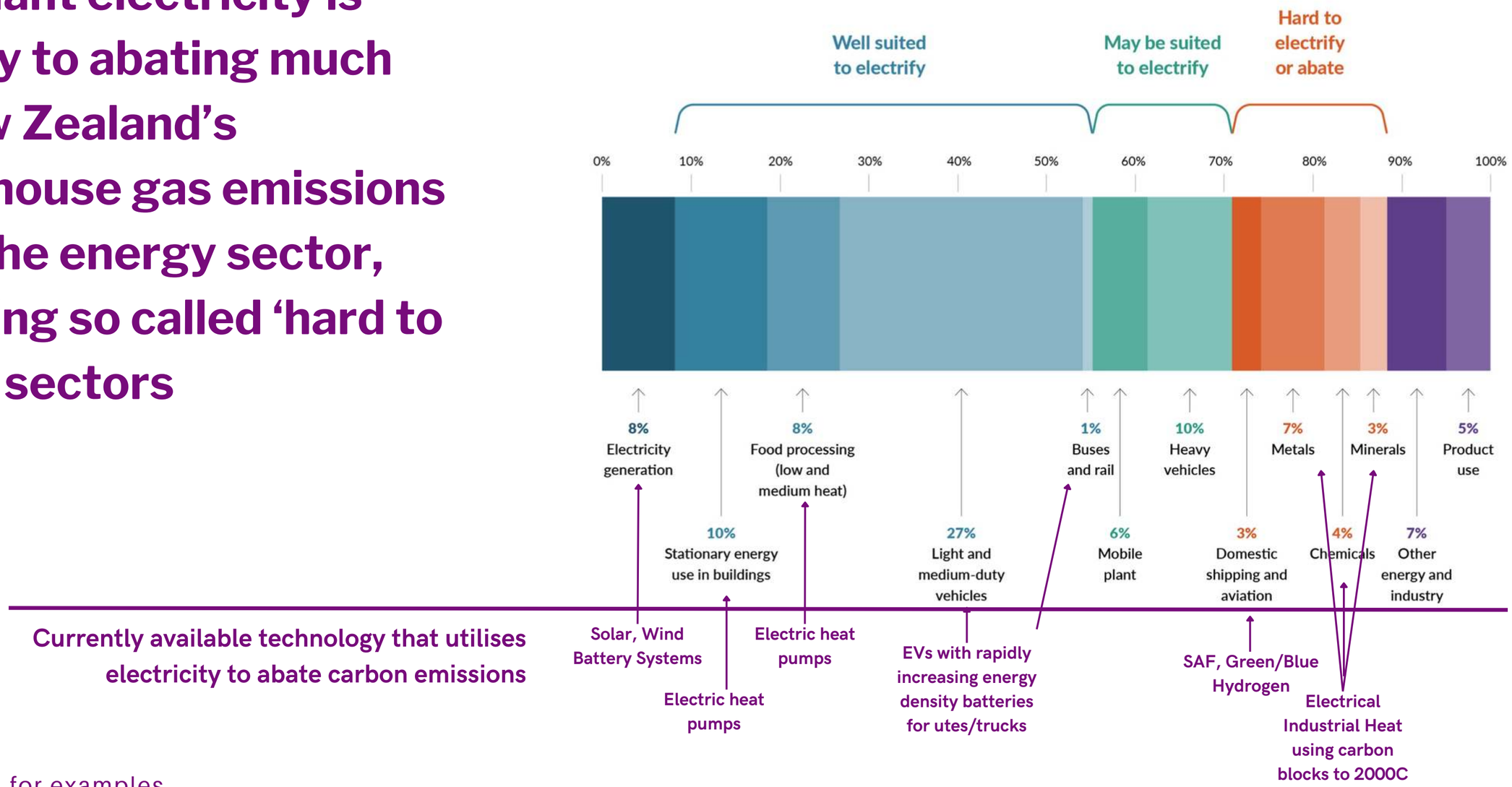


This goal will not meet the demand for energy by 2050 even if waste is mostly eliminated. Instead imagine if the ambition was to 2x growth in total energy supply (not just electricity) from 100% clean sources by 2050 by investing zero net new taxpayer dollars.

Source: MBIE, Ministry for Environment

Abundant electricity is the key to abating much of New Zealand's greenhouse gas emissions from the energy sector, including so called 'hard to abate' sectors

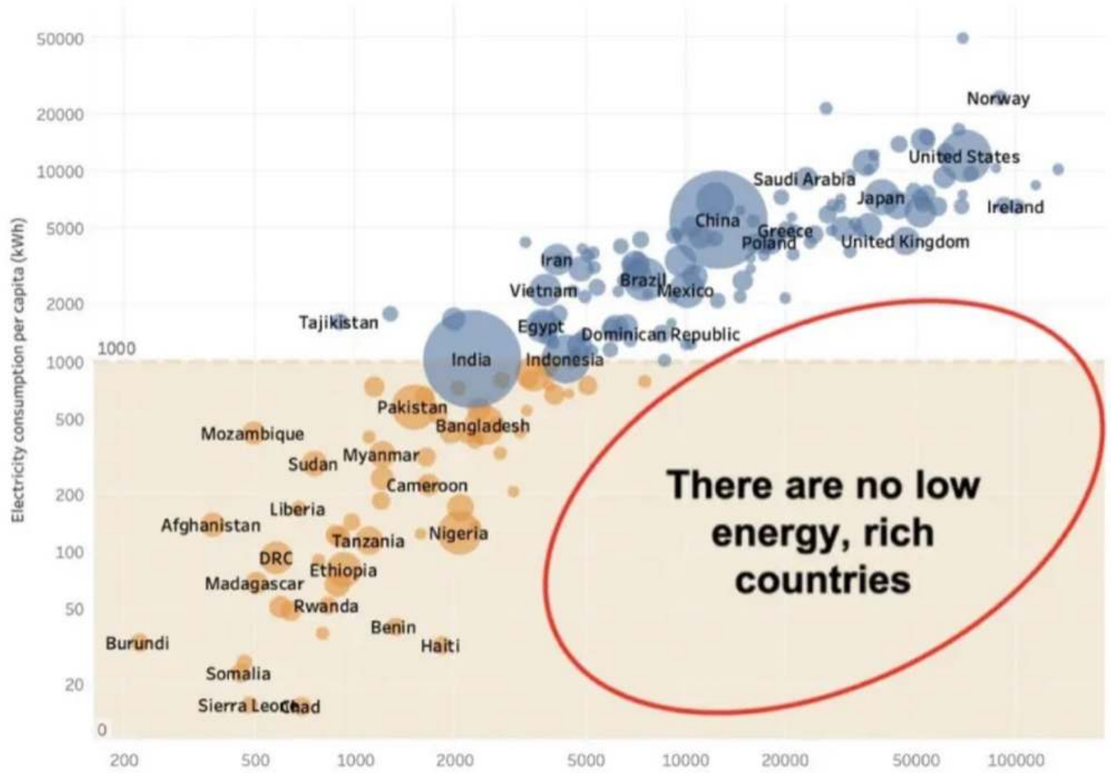
New Zealand's emissions from the energy sector and industrial processes, 2022



See slide 24 for examples

There is significant upside potential to moving early

Electricity consumption vs GDP per capita by country , 2021



Source: USEIA, World Bank

Securing energy self sufficiency in a volatile geopolitical environment.

Being at the forefront gives New Zealand entrepreneurs and businesses a head start on a transition with trillions of dollars of global value creation potential.

NZ can abate emissions without slowing economic growth.

Our 8 point plan to usher in clean abundant energy for New Zealand at very low cost to taxpayers by letting capitalism take over

1. **Reset the ambition** from ‘2x renewable production in 2050’ to ‘2x the total energy supply from 100% renewables by 2050’;
2. Prepare **strategies accounting for the exponential cost reduction** in solar, wind and battery technology - it is predictable;
3. Enable **broad-based participation in marginal supply and demand response**, unlocking latent demand in solar and battery storage with feed-in tariffs to reflect electricity spot market prices or regulated RAB-like returns;
4. **Incentivise residential and businesses to over-build** solar production and battery storage capacity with grid response capability;
5. **Review policy for gas-fired generation** in light of objective un-biased analysis accounting for the exponential cost reduction in SWB technology demonstrating that SWB systems will cost lower than the operating costs of gas-fired plants this decade;
6. Review policy for transmission and distribution sector to encourage **rearchitecting the system to enable distributed electricity generation and storage at scale** behind the meter while reducing investment in transmission and distribution monopolies;
7. Incentivise global and local startups to **use New Zealand as a testbed for scaling their decarbonising innovations**;
8. Encourage New Zealand-based **R&D on chemical electrolysis processes and catalysts**; this is one of the very large opportunities for value creation that gets unlocked by abundant clean energy at near-zero marginal cost.

WANT TO KNOW MORE? CONTACT US.



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