Imagine you and your loved ones have just been seated at a family restaurant, when a waiter arrives to blandly intone:

"Our specials tonight are either the *arsenic a la oilsands* with bitumen biscuits, or the *crepes Californium* with plutonium pudding. Other entrée's, salads and vegetables are not available at this time. May I take your order?"

This offer, of course, sets up doomed diners to pay their bill just before ending up on slabs at the morgue. And pity the poor, bewildered coroner who must identify the deadly stomach contents – in a hazmat suit.

Yet such a binary menu of equally fatal poisons is precisely what dominant energy incumbents and their enablers are framing as a crucial 'bridge' to some far distant renewable future. Fossil and nuclear lobbyists showed up in ever greater force at the 2022 COP 27 climate conference in Egypt, posing as save-the-climate crusaders.

But their bridge-to-be is so *last* century. On the metrics of cost, proven performance, reliability, public safety, meteoric scale increases, competitive ingenuity, supplier diversity, world security, cross-sector carbon reductions, and more equitable global wealth distribution, green power is now the best survivor game for our global village.

Where is that evidence? Everywhere – starting with a fusion fireball some 93 million discreetly distant miles away. Only a mere micro-fraction of its eternal energy output powers every form of life, and underpins every economy, on this Earth. That 'solar constant' in turn energizes every solar panel and wind turbine, fleets of which are being built at accelerating speeds and scales because their production costs are now lower than all their rivals.

Most thrilling, under construction now are battery storage and hydrogen technologies which will be paired with renewable power projects to deliver emissions-free power virtually anytime for heavy industries on every continent, or for sea-going ships or airline fleets.

This qualifies as miraculous. Yet it remains almost invisible because mainstream media platforms fail to calculate its *cumulative* global mass and velocity. At best the public is getting scattered snapshots taken at ground level, instead of a panoramic satellite survey.

Sceptics can consider this, for starters: In 2022 the combined installed electric power capacity for Canada was about 150,000 megawatts. That powered all the homes, farms, factories, auto plants, mines and metal smelters, office towers, businesses, schools, hospitals, libraries and recreation centres in an affluent G7 nation.

That same year, *300,000* megawatts of new solar panels were produced by just the top six global manufacturers. Wind farms added another 110,000 megawatts of peak output in 2022, bringing cumulative global wind capacity to almost one million megawatts.

How is it possible that solar and wind technology are already delivering each new year more than twice the total peak power capacity it took Canada a *century* to build?

The astonishing answer is that – from a manufacturing perspective – solar panels and wind turbines are more akin to flat-screen TV's, laptops and cell phones than giant coal, gas, and nuclear plants or hydro dams. Like other consumer products, copies can be made by the thousands or millions at hundreds of global production plants. It typically takes just 40 seconds on an assembly line to finish making a solar panel. A *single* new production-line wind turbine built for open ocean windfarms can power 136,000 homes annually.

This comparative simplicity and speed endows such green 'knock-off' technologies with the ability to out-compete fossil or nuclear rivals on cost, construction times and reliability. In Europe or the U.S., it takes more than a decade to licence and build a new 3,000 MW nuclear plant, while just the top tier of global solar companies can now punch out 300,000 MW of panels for installation annually.

That 100-fold difference in manufacturing scale also means – as with consumer electronics, Heinz ketchup, '60's vinyl rock records, or the iconic 1950's Volkswagen – that solar panel and wind turbine production costs per unit go down as scales and sales go up. Lower costs lead to even more sales, which drives investments to escalate scale and R+D spending to improve performance, and panel or turbine longevity.

This ascending green power success is due fundamentally to physics, chemistry and production economics, not environmental, public safety or job creation benefits. The latter can earn justifiable praise, but the former has recently brought some $US 800 billion to the table in capitalist, communist and some cleric-ruled countries because the risk/reward ratio is rock solid and market share beckons. In 2023, global green power capital investment is slated to exceed $US 1 Trillion.

In a word, 'replication' is the boring but potent secret sauce for solar and wind power. In contrast to mammoth, custom-designed nuclear and fossil fuel plants, stamping out countless identical units from 24/7 assembly lines underpins lightning production speeds, fast project construction time-lines, scalability and lower costs per unit.

Leading solar panel manufacturers also deliver a product with unique performance and longevity guarantees – because they have no alternative. They cannot qualify for large project contracts, or obtain bank financing or project insurance,

unless independent testing labs certify that their panels will generate their rated power for 25 years or more. This creates a gold standard of performance – one neither fossil fuel nor nuclear plants can match.

The 300,000 MW of new solar panels produced globally in 2022 testify to Henry Ford's venerable formula: make a Model A and copy, copy, copy. Better still, solar panels are essentially open-source templates (with zero moving parts) which can be made, bought, licenced, re-configured and upgraded by countless research labs, competitors, and global suppliers.

For that very reason, solar panel output per square meter has skyrocketed over the past decade by harnessing special crystalline materials like perovskite, and chemistries which convert more parts of the light spectrum into power. University, government and corporate labs are all racing to identify even cheaper, more efficient combinations from thousands of candidate materials. Some are using supercomputers and artificial intelligence to matchmake prospective winners.

Meanwhile, global nuclear plant capacity *fell* to its lowest level in four decades precisely because every reactor model features thousands of customized, complex parts and exotic materials made by a mere handful of specialist manufacturers. Operating under intense heat and pressure within withering reactor

radiation zones, they increasingly fail, crack and corrode with age.

This real-world reactor performance opens the door to extortionate payment demands for one-of-a-kind parts or repairs – even from the very suppliers responsible for egregious manufacturing flaws. After decades of paying merciless mark-ups, most utility operators now belatedly know those back-end blackmail costs are baked into the nuclear power business model.

Even more expensive surprises, and long construction delays, have plagued all of the new reactors under construction in England, France, Finland and the U.S. state of Georgia in recent years. Solemn vows to meet budgets and construction deadlines at their shovel-turning celebrations proved worthless. Yet again.

By contrast, utilities or power procurement entities around the globe are now driving down costs, and precluding sole-supplier squeeze plays, by holding perpetual green power auctions.

These pit dozens of solar panel makers, or wind turbine companies, against each other to win major long-term power supply contracts at guaranteed prices. A key feature is that these are 'pay for performance' contracts – winning bidders simply do not get paid if they don't deliver the electrons they promise.

This tough love dynamic forces green power developers to:

- build large solar or wind projects on budget
- scale up production at panel and turbine plants to drive down unit costs
- invest in innovations to improve performance
- typically complete large projects in less than two years

Green power thrives under such fiscal discipline because its top three trump cards are replication, replication, and replication.

In such a competitive arena, nuclear can't even get in the game, and new natural gas projects are fast becoming zombie options because they embed decades of future carbon emissions *and* global cost contagion risks due to wars, extreme weather events, and market manipulations by corporate goliaths, fuel brokers, and petro-state cartels.

Consider the energy and economic peril Europe faced in 2022 after Russian president Vladimir Putin cut key gas and oil exports as a way to punish NATO allies for aiding Ukraine following the illegal invasion ordered by Moscow.

Perversely, that drove *up* global oil and natural gas prices, which allowed Russia to garner windfall revenues to offset the cost of its brutal war on Ukraine. (Countries like China, India and Turkey covertly bought huge volumes of Russian oil at prices pegged below steeply increasing world prices). To hide this dirty

business, Russia bought a fleet of aging oil tankers, some of which became 'ghost ships' when their location transponders were turned off.

Simultaneously, anonymous broker-speculators in London, New York, Frankfurt, Beijing and Singapore made record profits stoking – with the click of computer keys – global panic buying of oil and LNG. Some oil shipping companies connived their own gouging, which was added to the delivered price per barrel.

All these machinations doubled the net income of fossil fuel majors to $US 4 Trillion in 2022, and brought annual global consumer spending on fossil fuels to $US 10 Trillion for the first time. This may have amounted to the biggest single reverse transfer of wealth in history – from the many to the *oil*-igarch few.

So, Putin made tyranny profitable despite lower volumes of Russian oil exports, and used net revenues to relentlessly attack Ukraine. Fossil majors like ExxonMobil, and predatory petro-states like Saudi Arabia, cashed in while spending virtually nothing on new refinery capacity. Finally, Putin also threatened Ukraine's largest nuclear plant, raising the spectre of a second Chernobyl catastrophe.

These chilling gambits illustrate how fossil fuels and nuclear plants can be weaponized, torqued and twisted to benefit many dominant energy players while putting the planet and its people in a world of hurt.

Now try to imagine how Putin could gain comparable leverage and lucre by declaring a halt on sales of Russian solar panels and wind turbines to Europe or threatening to aim artillery at solar or wind farms in the Ukraine. Such threats would be laughably impotent. This may explain why Putin's Russia has a negligible solar and wind industry, with nothing to export. But because the sun shines and the wind blows freely everywhere, and so cannot be monopolized or weaponized, green power technologies have intrinsic qualities that foster energy independence and minimize the blackmail tactics of despots, petro-states or climate-denying and defying behemoths like ExxonMobil.

Since mass produced panels and wind turbines come in countless models, from hundreds of suppliers in diverse regions, they are impervious to geo-political embargoes, economic extortion, cartel tactics and global price-fixing schemes. No 21st Century tyrant can succeed in cornering or even crimping such diverse, expanding global green trade.

Thus, the paths to a more peaceful and prosperous world are at hand because a dynamic triad – replication, innovation and scale-driven cost reductions – now allows 'electrify

everything' economies. The proof is embedded within countless on-the-ground green power projects now being built in astonishing ways and places across the globe.

So new iterations of a boring, century-old business model turns out to be the smartest, cheapest, fastest, safest and most elegantly functional way to re-invent humanity's future. Replication at scale is the catalyst. Hope beckons, because finally this green ascent has a global mass and velocity that is unstoppable.

****

While California and Canada are population twins – each with just a fraction under 40 million people – they are only distant cousins when it comes to setting the pace for solar and wind projects, electric vehicle manufacturing, auto pollution standards, advanced battery build-outs, and tough-but-fair pricing and regulations to foster a low-carbon economy.

Not to put too fine a point on it: California has been the leader, and Canada the laggard, for decades. And, despite 'the sky is falling' wails from Big Oil, Big Auto, the U.S. nuclear lobby and private electric utilities habituated to a century of monopoly practices, such green pioneering has not savaged the state economy.

Far from it. California now has the largest sub-national economy in the world. Ranked by nominal GDP, it is the

globe's fourth largest economy, and growing. It just passed Germany, the EU leader in green power innovation. Better yet, California achieved this status with a booming state budget *surplus* of US$ 98 billion, and green power has literally saved the state from catastrophic, costly grid failures due to increasingly destructive, climate-caused droughts and wildfires.

California achieved this with an in-state power generation capacity about half that of Canada, declining reliance on out-of-state energy imports, and the contribution of nuclear power cut by half during the last decade. The last two reactors still operating, at Diablo Canyon, are slated for retirement, and provide only nine per cent of the state energy. They sit on a major earthquake fault line, as does the now closed San Onofre nuclear plant. For reasons now obvious, there are zero plans to build new ones. Good call.

California's green ascent was not due to god-like prescience, or accident. It began in the 1980's because there was no other choice: a surging population brought vastly more cars, houses and air conditioning loads. Autos and power plants created pollution so bad that smog smeared the LA skyline, stung the eyes, and put kids and the elderly in hospitals.

That led to the creation of the California Air Resources Board, long spearheaded by Mary Nichols, its famously feisty clean air and climate champion. Combined with a Nixon-era concession that gave California the legal right to enact more stringent air

quality standards than those imposed federally, CARB pounced on previously unchallenged polluters.

Auto makers soon faced an array of 'tailpipe' regulations meant to lower emissions and raise fuel efficiency. There were carrots to entice compliance, but also one ominous big stick: the risk of being shut out of the California car market (1.8 million new vehicle sales in 2021) for those that failed to meet CARB orders. Opposition eventually collapsed into compliance. California proved too juicy a market to jettison.

A similar hard-ball tact was taken with large industrial polluters and power plants. As Californians garnered both cleaner air and more fuel-efficient cars, state legislatures and governors either openly backed CARB orders or kept their opposition off camera.

CARB's influence and impact increased multi-fold after an electricity system scandal early this century. California's attempt to de-regulate the power markets there led to calamitous results: an 800 per cent spike in generation prices; its major utility knocked into bankruptcy and another barely surviving; a secret deal sticking consumers with billions in future debts; a governor's fall from grace; and oblivion for the high-flying, low-down energy embezzler Enron.

Court testimony, investigative reports, and jailed executives later confirmed Enron, the original Grifter Of All Time, had

siphoned off billions by deliberately shutting down some power plants just as California was hard hit by months of drought.

The serial 'shortages' proved to be premeditated fraud, known only to a few by insider code names. Phony repair, breakdown and line overload claims were timed to sell power, at the highest prices possible, from other power plants Enron just happened to have waiting in the wings.

The scandal ended that state's doomed experiment with an electricity Wild West, and gave regulators there new powers to plan a cleaner, more stable grid and demand compliance from obdurate private utilities. Their marching order was: Pick the Lane to Never Again.

So, it took decades of lethal smog and the Enron scandal for Californians to accept tougher regulation as a means of protecting their air quality and pocketbooks. Now, twenty years on, the state leads the world in low-carbon progress. *And* it has a thriving economy. *And* a state budget surplus just shy of $US 100 billion.

Surely that is a prospect worthy of replication, replication, replication.

****

California is home to the world's first major plant to manufacture all-electric vehicles, Tesla. In early 2022 that car company had a market capitalization some five times larger than GM and Ford combined, led the state in total car sales, and its founder Elon Musk was one of the richest men on the planet with a personal wealth pegged at US$ 219 billion. That was before his autocratic management style, reckless U$ 44 billion bet to buy Twitter, and erratic edicts led to a 75 per cent meltdown in Tesla's share price in just twelve months.

Tesla also now has replica car factories in Texas, Germany and China. It built a giant gigafactory in Nevada (partly powered by its own rooftop solar panels) to mass produce lithium car batteries, then replica gigafactories in Europe and China. More are on the drawing boards. All this was accomplished on the premise of mass producing a green mobility product that could help save the planet.

But such success was not inevitable, and the brash, bellicose Tesla founder seems to have forgotten that his company averted the wrecking yard in 2009 because the Obama administration granted an emergency loan of US$ 465 million, and California regulators set up twin pillars which buttressed Tesla's survival.

First, CARB enacted the then strictest vehicle fuel economy and emission standards in the world, which forced domestic and foreign automakers to either meet ever higher fleet

averages, or pay stiff penalties, or forego sales of high-margin SUV and truck models in California.

Virtually all car makers howled in protest, except one. That was because the California rules also exempted all-electric car makers from such sales restrictions and bestowed highly valuable credits for every vehicle produced. Those pollution reduction credits, in turn, could be sold to rival car companies which failed to meet state emission regulations. These would offset cash penalties owing by Big Auto scofflaws to CARB.

Tesla, it turns out, was the only company which racked up huge credits to 'bank' and later sell in order to keep its flagship factory afloat. For almost a decade, Tesla produced escalating numbers of cars (and credits), but no actual profits. It was CARB that saved Tesla in its lean years. Later, similar regulations and credits were replicated in the EU, which kept Tesla viable there.

Elon Musk might be loathe to admit this, or that his coveted cars are the 21st Century version of a Model A, but he did intuit that replication at scale would eventually beat gas and diesel rivals, just as Henry Ford replaced horses. He knew all-electric vehicles have far fewer parts, leaner supply chains, quicker assembly times, and 'engines' comprised of tiny, silent, motionless mass-produced lithium batteries.

He also guessed that there would enough buyers from Silicon Valley, Hollywood and Wall Street and other elite enclaves who would gladly pony up for what a Tesla delivered: prestige, aerodynamic curves, wicked fast acceleration dubbed 'insane mode', instant torque, and a whisper-quiet, elegant ride with a plug-in fuel cost per mile about 70 per cent lower than the internal combustion competition.

In his more noble moments, Musk the Younger was a green apostle who bet his fortune on combatting climate change, built Tesla charging units across North America, and even released key patents so that others could replicate what he pioneered. Rivals eagerly snapped those up, and are now making electric vehicles in the U.S., China, Europe, and India (where that nation's largest industrial conglomerate is tooling up to produce an EV with a US$10,000 price tag).

Elon Musk's notable legacy is that rivals like Volkswagen and Volvo are now replicating the Great Replicator world-wide, and he proved that emission-free batteries paired with highly efficient electric motors can conquer one of the toughest sectors to crack in the race to avert climate peril.

Now the EU nations, England, China and Canada are among two dozen countries, U.S. states and Canadian provinces which have followed California's lead and pledged to phase out the century-old reign of internal combustion engines within two

decades. From then on, new passenger car sales would be solely electric.

The major global automakers have added up all those pledges and are now beginning to re-tool for a world where the market to replace 1.4 billion existing vehicles with battery-powered models gleams like a showroom Tesla. Amen to that.

****

The Apple iPhone is a quintessential Silicon Valley invention because it combines a sleek 'less is more' exterior design with an interior 'more is more' computing powerhouse that can be held in the palm of a hand.

Of course, it is not merely a mobile phone. It has become a shape-shifting camera and video creator, limitless jukebox, movie streaming screen, digital mailbox, world mapping service, coffee shop locator, social media conduit, heart monitor, calorie calculator, appointment manager, garage band promoter, game arcade and banking device – among countless other apps.

The genius of Steve Jobs was that he understood how this multi-dimensional value could be packaged into a shirt pocket or purse-sized device which could be replicated, replicated, replicated – then sold, sold, sold.

Before Elon Musk, the Apple founder put his company fate on the line to build production plants and bank on soon-to-be smitten customers. They came in serial tsunamis, and inevitably

rival companies displayed the sincerest form of flattery by imitating Job's replicable device.

The iPhone success had a hidden formula: it combined Moore's Law relating to the exponential powers of micro-chip density, and Wrights Law which predicts how replication (doubling of production) leads to lower costs. Now those Laws, in tandem, are turbo-charging green power in California and the world.

Take the Tesla. Until recently, electric utilities and EV's had a strictly one-way relationship: grid electrons raced through a charger cord to the plugged-in car battery. But now many EV models, which feature some 100 million lines of computer code and a powerful lithium cell pack, are capable of sending juice *the opposite way* when utilities need it most and will pay premium prices for it.

This makes the Tesla, and other EV models by Nissan, Hyundai, Volkswagen, BMW, Ford and GM not merely *cars and trucks*, but micro power plants on wheels. Software apps and bi-directional charging cables now allow owners to send power to grids (V2G), but power to everything else (V2X) including a house when power is lost, a rustic cabin, a construction site, or an off-grid lodge or outdoor rock concert.

But the biggest value awaits from EVs which are parked, on average, *about 95 per cent of each day*. Some stay motionless for days or even weeks, such as those at ocean port offloading lots,

school bus depots, car dealerships or airport car rental berths. Case in point: Hertz has ordered 100,000 Tesla's, 65,000 from Volvo/Polestar, and another 175,000 EV's from GM.

Thus, it is now possible to earn income by sending hundreds or thousands of computer-orchestrated jolts of power, at precisely the right time, to utilities in need of instant power. Or to offset generation from their most carbon-intensive sources.

As well, it has now been demonstrated that when EV batteries are no longer powerful enough to drive a vehicle, they can be bought by utilities, industries or critical facilities like hospitals, then aggregated by the dozens or hundreds to provide cheap but reliable emergency power, or peak demand assistance.

At an iconic soccer stadium in the Netherlands, banks of used Nissan Leaf EV batteries were set up in 2018 to provide match day power, while the parking lot has been partially converted to use solar panel canopy's with EV chargers underneath. A replica followed in Norway. More are planned. Once such 'second life' batteries are fully depleted, the lithium can be extracted and recycled into new battery packs for cars or other consumer products.

So eventually, as the existing world fleet of vehicles is replaced, 1.8 billion replicated EVs with replicated, recyclable batteries can cut related gasoline and diesel combustion when they are in motion. That alone will be a huge win for the climate. But they

can also aid electric grids plagued by climate-caused events when they are *parked*. Call that moonlighting, or double-duty carbon busting.

Yet what might happen when lithium batteries, solar panels and wind turbines all combine to form grid-connected generation on one site? The powerplants for an 'electrify everything' economy could emerge.

Actually, America's first such 'trifecta' project is already operational in arid north central Oregon. On a single site are 120 wind turbines which can churn out 300 MW, solar arrays which can provide 50 MW peak output, and a lithium battery storage system that can send 30 MW – when it is needed most – to a utility in Portland. At peak output, the site can supply enough power for a small city. Symbolically, it went on-line just after Oregon's last coal plant was decommissioned and demolished.

The Oregon project components are complimentary because the solar system performs during daylight, while the area winds are strongest at night. Any surpluses can be stored to match peak power demand, maintain grid voltages, and balance demand/supply fluctuations.

That kind of 'trifecta' payoff can be replicated anywhere solar and wind conditions allow, because battery storage systems can be located wherever shipping containers can be delivered. For

example, the coastlines of Africa, Brazil, India and Australia are prime real estate for such projects.

Spoiler alert: An indomitable Australian billionaire both admired and scorned in the down-under continent as 'Twiggy', is now betting an immense fortune on just that.

Andrew Forrest became the richest mining tycoon in 'Oz' by digging up prodigious amounts of China-bound iron ore from western Australia's coastal Pilbara region. That, he publicly concedes, burns up a lot of fossil fuels (creating 2 million tonnes of greenhouse gases annually). Diesel is also Fortescue Metals' major operational cost.

Those twin realities seem to have triggered a later-life conversion to the low-carbon cause. He showed up at the COP 27 climate conference in Egypt in late 2022 as a green power crusader (albeit without a cape or Marvel movie deal), gobsmacking those back home in his industrial fraternity and conservative political circles.

But it seems as if 'Twiggy' will walk the talk.

"We have to crack on," Forrest declared on his return. *"We share a vision of Australia and the world, looking back on the dark era of fossil fuel as an aberration in humanity's history."*

Gobsmacked indeed.

Before the Egypt event, Forrest locked up billion-dollar deals on opposite coasts of Australia to assemble 'trifecta' power parks through the private company he controls, Squadron. The stated goal is to de-carbonize heavy industries, including Fortescue. He also bought into a consortium planning an ocean-floor transmission line to export solar power from northern Australia to Singapore. Estimated to cost US$20 billion, it has been dubbed the "Sun Cable".

Only weeks after his return from Egypt, and now in stealth mode, his company Squadron outbid domestic and international rivals to buy a formidable package of existing and pending wind, solar and battery projects for A$ 4 billion.

Together with the planned US$ 2.2 billion Clarke Creek project in Queensland, and his west coast Pilnbara project, this will give Squadron green power dominance on three of four Australia coastlines and make 'Twiggy' the leading owner and promoter of 'trifecta' projects.

Your hero cape is almost ready, sir. *Crack on.*

****

Perhaps no one has ever put the words 'Twiggy' and 'Saint' in the same sentence, and certainly won't unless the mining magnate Andrew Forrest matches words with deeds. One good

sign is that the billionaire has effectively shunned both nuclear power and fossil fuel carbon capture as Australian solutions to the climate crisis.

Instead, he has gone straight to the 'trifecta' technologies which can be replicated – and thus are the fastest, cheapest, most agile way to cut industrial carbon emissions.

For some uses, Forrest has declared, green hydrogen can replace lithium as the battery of choice once electrolysers (which can use high voltage wind and solar farm power to separate hydrogen from oxygen in ordinary water) get to scale and then the replication stage.

'Twiggy' has vowed to do just that. But he is not alone. Other consortia in Europe, the U.S, South America, China and the Middle East are planning similar 'trifecta' green power projects using either advanced batteries or hydrogen to store and deploy emission-free, on-demand energy for heavy industries. This would conquer the last concentrated stronghold of fossil fuels.

Most exciting, we can now see that Moore's Law and Wright's Law will almost certainly underpin the advent of a global hydrogen economy – as they have for the iPhone, solar panels, wind turbines, Ev's and advanced batteries like those made with lithium or vanadium.

The electrolysers which allow hydrogen to be captured and bottled can be scaled from 100 MW to a mere 100 kilowatts or less. Those can be located at huge 'trifecta' sites, or remote villages and refugee camps in Africa, Asia or South America. They could power a steel mill in Sweden, a freight train, a bus in New York or Bangkok, or a health clinic and school in Amazonia because hydrogen can be shipped in a pipeline, or by boat, or in a 'bottle' (like a propane tank) to locations far from electric grids.

On the manufacturing front, hydrogen electrolysers can be built on a scale as big as an oil refinery, but also punched out on assembly lines just like Tesla's, big rig engines, or commercial deep freezers and backup generators. They can then be paired with solar or wind farms, or both, or with rooftop solar arrays at malls, big box stores and warehouses to supply power, heat and cooling.

The current barrier to a global roll-out of this is financial, not technical. Norway proved a century ago that green power (from a hydro site) can make hydrogen at scale. Natural gas does that for industrial purposes now – but with the liabilities of both overt carbon emissions and far more potent covert ones like upstream methane flaring.

Blessedly, the 'electrify everything' and 'hydrogen economy' prospects have recently been upgraded, because new solar and wind farms now deliver the lowest cost electricity on the

planet. By 2030 the life-cycle cost of utility-scale green power paired with hydrogen electrolysers is slated to be lower than any other new power generation – including nuclear or natural gas.

Re-enter California and CARB. Both want to keep their status as low-carbon leaders by phasing out natural gas power plants, halting natural gas hookups for new homes, businesses and civic sector buildings like schools and hospitals, and helping to underwrite efficiency solutions like building design, insulation and heat pumps.

As with Germany, no new nuclear plants of any size are on order in California. Been there. Done that. Lesson learned.

But there are dozens of approvals pending for huge solar, wind and battery generation projects, with more joining the queue by the month. In the past, they have been proposed and approved as stand-alone generation because green power 'trifecta' projects did not qualify for a full range of federal tax write-offs, while private utilities in California resisted paying for the multiple benefits hybrid projects such as that in Oregon offer.

This undercut the economics and construction prospects of superior hybrid projects in the U.S. because key tax benefits and legitimate revenues for services rendered were missing from their spreadsheets.

Now that has all changed. A federal bill enacted by the U.S. Congress in 2022 has caught up with many technology advances (including lithium and hydrogen storage) so that 'trifecta' projects can finally gain federal tax advantages proportional to their total carbon-busting value. Simultaneously, California regulators have ordered utilities to compensate such projects for key services like on-demand supply, grid load balancing and voltage regulation.

Soon, that will likely lead to a 'back-filling' boom at existing stand-alone solar, wind or battery sites in California, in part because the new additions can share common transformer stations, grid connections and transmission capacity. As well, they will stoke construction of vast new wind farms off California's Pacific coast, for which federal marine leases were awarded for the first time in late 2022.

Those could feed both the California grid, and banks of on-shore electrolysers making hydrogen to meet grid peak demands, or power heavy industry, or fill ocean container ship fuel tanks at a co-located marine terminal. Similar projects are already being planned in Dubai and Australia. In Texas, a planned US$ 4 billion 'trifecta' green hydrogen complex will be powered by 1,400 MW of combined wind and solar capacity and produce 200 tonnes of hydrogen daily for industrial uses.

Meantime, some of the oldest green power sites from California to Texas to Montana will be retro-fitted with new, far more powerful solar panels and wind turbines. This will avoid buying or leasing new lands, while boosting output using the original costly racking systems and connection infrastructure.

Similar sea-changes in regulation and tax benefits occurred in 2022 in both the EU (triggered by the Russian invasion of Ukraine and the Putin-ordered halt in gas and oil shipments) and in Australia. That has ignited credible pledges to build 'green hydrogen hubs' from Sweden to Spain to the northern Sahara, and may partly explain why Andrew Forrest has embraced a green "go big or go home" business plan in Australia.

It will take a decade for 'trifecta' battery and hydrogen projects to be operational on a large, cumulative scale but there are now financial structures and regulations in place (similar to past CARB regulations which benefitted Tesla) to give renewables the fiscal footing to fight fossil fuels head-to-head. And leave nuclear die-hards whistling past their graveyards.

If the mass production past is prologue, green power will win the race to bring a low-carbon world with replication, replication, replication. Such a victory could confer a more secure, prosperous, and equitable future for eight billion people, and perhaps rescue the only breath-taking biosphere known to exist.