A $3.5 billion science experiment in Kurnool, a remote, hilly district in the southern Indian state of Andhra Pradesh. *Bloomberg*

Opinion | Andy Mukherjee

Want to Save the Planet? Re-Industrialize

Hitting the brakes on growth isn't fair to poor nations when a low-carbon economy is possible around what are now heavy, dirty industries.

By Andy Mukherjee

16 May 2023 at 01:30 GMT+5:30

Just as the machine-smashing Luddites of the 19th century were wrong about the consequences of technical progress for jobs, so may be the champions of the more recent theory of "degrowth." Sold as our best chance against global warming, it threatens to trap 80% of the world's population at living standards the developed world would never tolerate.

In the 1970s, the Romanian mathematician Nicholas Georgescu-Roegen posited a thermodynamic rule for when humankind exhausts its supply of fossil fuel. Economic activity, he said, would inevitably slow to a level supportable by solar flows. A corollary of that idea is that since in most places the sun shines for only half a day, billions of people in Asia, Latin America and Africa should simply accept that if they tried to get as rich as people in the West, their lands, livelihoods and lives would be visited by all the freaky calamities associated

with climate change: heat waves, droughts, flash floods, coastal sinking and bleaching of coral reefs.

A utopian social movement has coalesced for some time around ending the post-World War II obsession with gross domestic product and replacing it with "good domestic product" – output that excludes bad stuff like wars and ecological disaster. The concept has support in Europe, where half the population is older than 44 years. But developing nations aren't convinced that GDP growth is a problem just when it's their time to be the epicenter of production and consumption. Although China is also aging and slowing, it's still an upper-middle-income country, not a rich nation. India is a lot younger, and poorer.

The two emerging giants have more than just an ideological point. In their view, technology can even now enable people everywhere to aspire to a more prosperous life next year – and the year after – without destroying the planet.

To see why the optimists may be right, I went to visit a $3.5 billion science experiment in Kurnool, a remote, hilly district in the southern Indian state of Andhra Pradesh. The project site nominally falls in a forest, though it's mostly just barren, rocky land.

Work was in full swing on the eight turbines that would, by this time next year, rotate and generate current when water comes gushing down at them from an artificial reservoir. This water, held initially in a lower receptacle, will get pumped up to the upper lake by power harvested from the sun and the wind. Nature's bounty would be converted into potential energy before it's released into electricity via kinetic energy. The technical name for this is pumped-storage hydropower. Europe calls it a water battery. The grid, supplied by the 816-megawatt solar park in the project's vicinity, will get steady round-the-clock power, just as it would from a coal- or gas-fired plant. But minus any pollution. Water storage will boost the efficiency of solar to 80%-plus, a fourfold increase.

Greenko's pumped-storage facility. *Photographer: Andy Mukherjee/Bloomberg*

The project, which will effectively turn 4,000 megawatts of intermittent solar and wind energy into firm, schedulable power, is being run by Anil Chalamalasetty and Mahesh Kolli. The tech entrepreneurs, who met in London in the late 1990s, wanted to return home to India armed with European environmental technologies. Brainstorming sessions at The Pepper Pot, a pub near Tower Bridge, drove the pair headlong into the post-Kyoto Protocol zeitgeist of carbon credits. Greenko Group Plc, the firm they listed in 2007 on AIM, the London Stock Exchange's market for small and midsized companies, ventured into biomass, hydro, wind and solar. (Chalamalasetty also bought the pub after he realized their bills alone were enough to cover the mortgage.)

By 2017, the duo had delisted from AIM, raised money from the sovereign wealth funds of Singapore and Abu Dhabi, and set up in Kurnool what back then was the world's largest, single-location solar farm, spread over 24 square kilometers (9 square miles), or about 3,500 soccer fields. But then, the cofounders stepped back. There wasn't much joy, they decided, in merely producing the next green *electron* for power utilities. What the world really needed was the next green *molecule*. "We didn't want to be in the gigawatt game," Kolli told me. "We focused on decarbonization via re-industrialization."

Imagine making heavy, polluting materials like steel, aluminum and plastics with clean energy tapped as a service. Chalamalasetty, a computer science graduate, likes using metaphors from

the software industry. “We’re building the world’s largest energy storage cloud platform,” he says. Just as cloud-stored email comes to our phones when we need it, industrial customers can access renewable power any time of the day or night. It’s already happening. Starting June next year, ArcelorMittal SA’s Indian joint venture with Nippon Steel Corp. plans to cut 1.5 million tons of carbon emissions annually by taking as much as a fifth of the power need of its plant in Gujarat state from the facility I visited in Andhra Pradesh. Aluminum maker Hindalco Industries Ltd. will run smelters with 24x7 green energy, reducing another 680,000 tons of emissions every year.

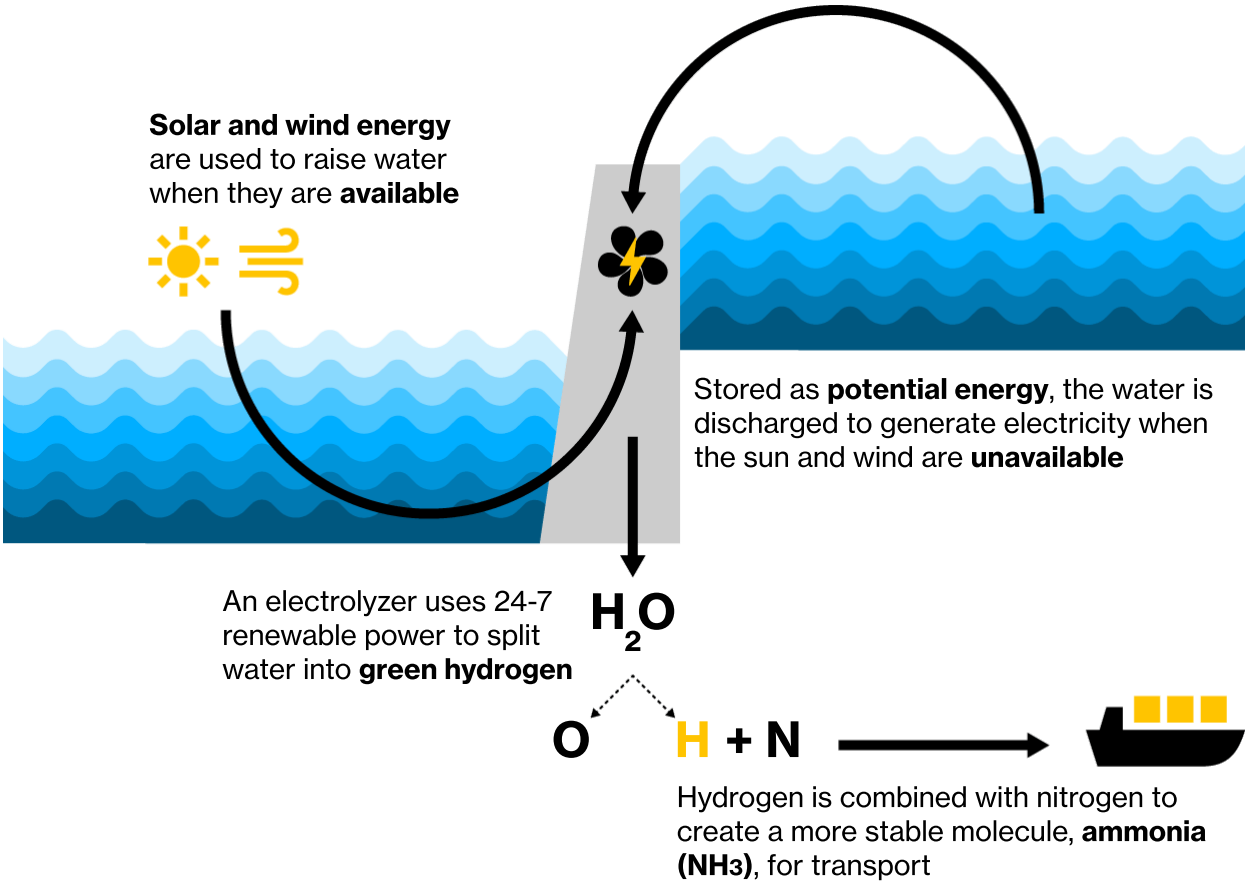
Kolli (left) and Chalamalasetty (right) at Greenko headquarters in Hyderabad. Behind them is a model of the Kurnool integrated renewable energy project. *Source: Grenko*

In India and nearly everywhere else, utilities are the main customers of solar and wind power. But electricity is only one part of our carbon footprint. Using inexhaustible resources to reboot vital industries may offer an escape route from Georgescu-Roegen’s entropy law. The only glitch is that renewable power isn’t always available. Storing it for when the sun doesn’t shine or wind doesn’t blow requires huge batteries that must be cheaper, safer and longer-lasting than the lithium-ion variety used in electric vehicles. That’s where the physics of pumped-storage comes in – supplemented by the chemistry of ammonia.

Every year, farmers use a big chunk of the 175 million tons of ammonia, or NH3, produced at a great cost to the environment due to the massive amounts of carbon dioxide released in the underlying industrial process known as Haber-Bosch. But while agriculture needs ammonia for its nitrogen, a crop nutrient, Greenko is interested in NH3 as a carrier of three hydrogen atoms, cleanly produced.

Solving the Intermittent Renewable Problem

A pumped-storage hydropower system brings down the price of renewable electricity by making it available round-the-clock



As a feedstock and fuel, hydrogen has the potential to be the chief building block of the next Industrial Revolution.

Traditionally, most of our hydrogen has come from hydrocarbons. Gray and brown H2, produced from gas and coal, is the 94-million-ton-a-year bedrock of fertilizers, plastics, textiles, and a lot else besides. While it feeds and clothes us, it's also highly polluting. Blue hydrogen, derived from natural gas with the residual carbon dioxide captured, is what countries like Saudi Arabia are pushing as an cleaner alternative. But the breakthrough lies in sidestepping carbon altogether.

The hydrogen we need is the green version, extracted from water and not hydrocarbons. The energy required to split open the water molecule will be solar or wind, arriving in electrolyzers via water batteries. Extract hydrogen from water, synthesize it with nitrogen using an electrical, rather than methane-fed, Haber-Bosch process, and you have carbon-free ammonia. It can be transported more easily and safely than shipping hydrogen as a gas or liquid. Then, either use the green ammonia to make fertilizers or break it up in a cracker into hydrogen with the help of a catalyst and more renewable energy, and use it in a fuel cell. What will be left behind will once again be just H2O – water.

It's this green variant of H2 that would truly transform global trade by prizing open up the cozy club of energy exporters.

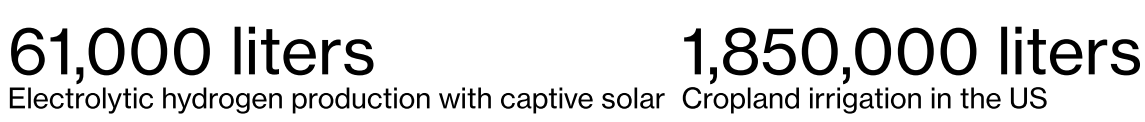
Ethiopia is awash with photovoltaic potential, as are Pakistan and Somalia. Selling today's sunshine won't leave a poor nation worse off tomorrow. The usual socioeconomic concerns with resource extraction won't apply.

An electric-vehicle revolution doesn't exactly pass the test. Keeping EVs affordable means intense mining for lithium, cobalt, and nickel, something that's already proving to be problematic: The Chilean government plans to demand a controlling stake in all future lithium projects; cobalt mining in the Democratic Republic of Congo has ignited worries about modern-day slavery. By comparison, switching to green hydrogen to save the planet is unlikely to cause new headaches. Replacing the entire current global production of conventional H2 with its electrolytic cousin would require roughly 0.09% of freshwater withdrawals, according to BloombergNEF, an improvement over the status quo.

The 24x7 renewable energy required for H2O electrolysis could come from pumped-storage units where water is swapped between two custom-made reservoirs that don't rely on rivers for a refill. These are cheaper and faster to build than half a century ago, when Europe and the US started exploiting the height difference between two natural lakes. The original aim was to help nuclear-power plants, which couldn't ramp up or down, deal with night-time demand drop. The newer-vintage water batteries are larger and more ambitious. They can last for half a century, without emitting noxious fumes. As for carrying green H2 around the world, ammonia, the "transport battery," could be put on ships that are themselves powered by carbon-free NH3. None of this stuff is science fiction; the first of those vessels may arrive in a year or two.

Green Hydrogen Won't Drain Our Water Resources

One acre of solar-based hydrogen would require 61,000 liters of water per year, 30 times less than an acre of US farmland



Source: BloombergNEF

The new hydrogen-centric economy is attracting funding. According to BloombergNEF, annual H2 demand may quintuple to 500 million tons by 2050. Generation plans need a huge boost. To get there, the US has earmarked $9.5 billion in grants and announced production tax credits under the Inflation Reduction Act. Germany will spend $21 billion by 2026. The Port of Rotterdam is studying the feasibility of an ammonia cracker. South Korea is building a green ammonia-import terminal.

Green hydrogen could also cut down the outsize role of oil and gas in geopolitics. There will be less human conflict over finite hydrocarbons. The wars that get counted in GDP would give way to better-quality national income, answering at least one criticism of the modern way of life by the advocates of degrowth. For a true revolution, however, the economics must work out for everyone. India alone consumes 7 million tons of gray H2 annually – more than all of Europe combined. Industrial customers in poor countries can't pay $6 for a kilogram of green hydrogen. Nor can their taxpayers afford to slash that price by half by mimicking the US subsidy.

This gridlock may keep re-industrialization a pipe dream. The good news is that developing nations are replying to the challenge. One kilo of green H2 selling for $1 within a single decade, what the Indian tycoon Mukesh Ambani calls his "1-1-1" vision, may be too far-fetched. Geenko's more realistic goal is to beat liquefied natural gas, the source of gray H2.

Once known as the champagne of fuels, LNG is better for the environment than coal, but its price can be erratic. Last year, Asian importers, from India and Bangladesh to Thailand and the Philippines, were being asked to pay $30 or more per million British thermal units because of Russia's war in Ukraine. That's roughly equivalent to $6 for a kilo of gray hydrogen. Greenko ZeroC Pvt., a subsidiary of the Indian firm, expects to deliver a green version, produced with round-the-clock renewable power, at $3 without subsidies. It's confident of meeting that price because of the low cost of pumped-storage hydro. Lithium-ion batteries, anyway unsuitable for long-duration storage, will be more than three times as expensive at current prices.

Under construction. *Photographer: Andy Mukherjee/Bloomberg*

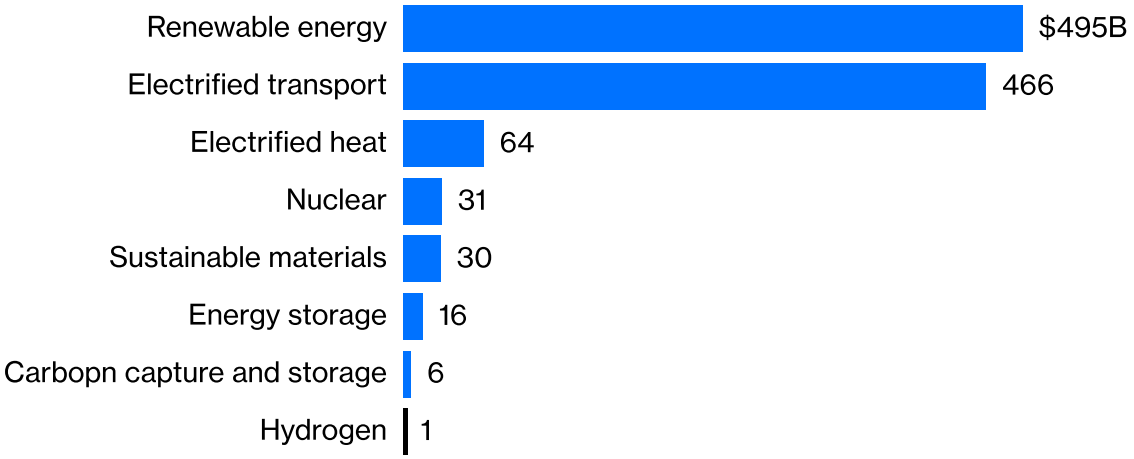
The physics of the water battery, fused with the chemistry of ammonia, may offer the best chance to rewire production, trade and consumption without accepting a decline in living standards, or raising the temperature so much more than 2 degrees Celsius over pre-industrialization levels that life for most people once again becomes nasty, brutish and short, if not downright impossible.

India gets a bad rep for contributing to that dystopian future because of its reluctance to retire coal. What critics miss is the behind-the-scenes work it's putting in. The state-owned NTPC Ltd., the country's largest power producer, recently invited bids for 9,000 megawatt-hours of round-the-clock storage of wind and solar electricity. The biggest US facility, by contrast, will only stock 3,000 megawatt-hours after an upgrade. One of its battery packs caught fire last year.

Climate leadership is moving east, but in a cooperative manner very different from how colonial powers had violently shifted the center of economic gravity westward in the 1800s. Greenko and Uniper SE are pursuing a deal under which the Indian firm's ZeroC unit will supply the German utility 250,000 tons of green ammonia annually. Korea's Posco Holdings Inc. wants to crack ammonia into H2 for its steel plants. Singapore wants to build ammonia bunkers for the shipping industry. ZeroC has entered into an agreement with the city-state's Keppel Infrastructure Holdings Pte. to explore building a factory together. With Belgium-based John Cockerill, ZeroC is setting up a gigafactory to make electrolyzers that would split water into hydrogen and oxygen.

Hydrogen Is Just Getting Started

Just about 0.1% of last year's $1 trillion-plus investment in energy transition went to what might be the fuel of the future



Source: BloombergNEF

Greenko has its headquarters in Hyderabad, a three-hour drive from Kurnool. The thriving metropolis of 10 million people is a testament to the kind of growth most cities in India are yearning for. GIC Pte, the sovereign fund of Singapore, owns a majority stake in Greenko, which also has a billion-dollar investment from Japan's Orix Corp. Access to global capital is allowing cofounders Chalamalasetty and Kolli to work off a Chinese template. China is rushing to meet its goal of 200 pumped-hydro facilities with a combined capacity of 270 gigawatts by 2025. Assuming

nine-hour storage, that's 2,430 gigawatt-hours of electricity, more than 24 times what Greenko is constructing and developing across seven locations.

That shows two things: One, China is reading the tea leaves right. As Europe seeks to put a fair price on the carbon footprint of imports, the world's lowest-cost producer of goods will be ready to meet the challenge. Two, India needs to catch up. Almost 45% of the workforce is stuck in low-wage agriculture, and the number has risen because of the pandemic. Without rapid urbanization, tens of millions of Indians will be left stranded as surplus farmhands. The question is whether the energy they guzzle on their way to a better life will be as reliable as coal and cheaper than imported gas – and if it will be environment-friendly.

At the United Nations Climate Change Conference in Glasgow in 2021, India promised a 45% cut in the carbon intensity of its economy by 2030, compared with the levels in 2005. That pledge won't be met by replacing coal-fired electricity with more solar and wind. India has auctioned an average of 15 gigawatts of renewables capacity annually in the last five fiscal years. In the next four, the government wants to triple that number . Merely flooding utilities with cleaner power during non-peak hours won't make growth carbon-free. It may only leave the world's fifth-biggest economy with wasted electricity and collapsed grids.

Storing sunlight cheaply when it's not needed and using it in a reimagined industrial supply chain may be the only sustainable path. If 1.4 billion people can achieve a responsible transition to high-middle-income status, rich and poor nations alike will grow a keener interest in the trinity of solar power, water batteries and green hydrogen – transported over large distances as ammonia. That will also go a long way in diminishing the halo around degrowth.

Even Georgescu-Roegen, who died in 1994, would have been dismissive of holding nations down. "Not only growth," he theorized, but "even a declining state which does not converge toward annihilation, cannot exist forever in a finite environment." His pessimism was rather more fundamental: "Perhaps the destiny of man is to have a short but fiery, exciting, and extravagant life rather than a long, uneventful, and vegetative existence," he wrote in 1975. "Let other species – the amoebas, for example – which have no spiritual ambitions inherit an earth still bathed in plenty of sunshine." Proving him wrong may well be the humankind's biggest preoccupation in this century.

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