ESR NEWSLETTER
December 2022

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1.Kicking our economic growth addiction

Larry Elliott, Guardian website, 17 Nov 2022

For the best part of three centuries, there has been a consensus about the goal of economic policy. Since the dawn of the industrial age in the 18th century, the aim has been to achieve as rapid growth as possible.

It's not hard to see why there has been this focus. Growth has raised living standards, increased life expectancy, improved medical care and resulted in better educated, better fed populations.

Indeed, it is a mark of how successful rich western countries have been in lifting people out of poverty that developing countries are keen to have what we've had. If faster growth means cleaner drinking water, more children in school and fewer mothers dying in childbirth then the world's poorer nations want more of it.

But there's an obvious problem. If developing countries are to have the same – or even remotely the same – standards of living as developed countries, that means a lot higher use of resources and additional pressure on the planet. It means an increase in energy use and the risk of an irreversible global climate crisis.

Given the existential threat posed by global heating, the concept that growth is good is being seriously challenged by those who say policymakers should be aiming for zero growth or even degrowth economies, ones that are shrinking. The idea that faster growth is the solution to every problem is no longer tenable.

Achieving a steady-state economy or degrowth is not going to be easy. Far from it, it will be hellishly difficult. For a start, it will mean changing the way we think about

economic success. Political debate is conducted by parties that vie with each other to promise voters the best growth strategy. Language matters, so when GDP is rising, that's good news, and when it is falling, it is bad news. Countries are judged by where they sit in international league tables of growth.

That's because over many decades, people – especially the most vulnerable – have found that degrowth has not been good for them. Recessions are a form of degrowth, and they result in unemployment, bankruptcy, homelessness and hardship. Recessions also mean politicians tend to double down on growth, fearful of a backlash from voters if living standards are falling. Faced with the choice between higher use of fossil fuels or having the lights go out, governments have opted for the former.

The only way to make a steady-state economy achievable is to harness an anti-poverty strategy to a pro-planet strategy. It is just about possible to imagine western societies where – after some vigorous redistribution – everyone has the income, wealth and time to lead a good life. But even that's not going to be enough. What's needed is a global strategy that encourages poorer countries to meet their legitimate anti-poverty goals in a way that is least harmful to the environment.

Britain accounts for 1% of annual CO2 emissions, whereas China and India account between them for 36%. African countries have much smaller carbon footprints, but they are likely to grow as populations rise and demand for energy increases. The UK could speed its progress towards being a net zero economy, but unless that was accompanied by deep cuts in fossil fuel use by much bigger emitters of greenhouse gases, it would have no discernible impact on rising global temperatures. Western countries can – and should – set an example with speedier transition to cleaner energy, but it is naive to imagine poorer countries are going to go for degrowth any time soon.

That doesn't mean the idea of a steady-state planet is a pipe dream. It does, though, suggest that the immediate priority should be to make developing country growth as clean as possible. And that needs more than warm words. It requires big money: $2tn each year between now and 2030, according to one estimate.

The aim should be a new version of the postwar Marshall plan, in which finance provided by governments and the international financial institutions acts as the catalyst for private investment. Avinash Persaud, the special climate envoy to Mia Mottley, the prime minister of Barbados, rightly says that the International Monetary Fund and the World Bank could be doing more to provide developing countries – many of which are burdened with high debts and punitive borrowing costs – access to cheaper finance to fund climate mitigation and adaptation projects.

Failure to mobilise the necessary resources would be disastrous but, tragically, all too likely. Western governments are assuming that they have all the time in the world to make tweaks to their business as usual models. The brutal truth is that they don't.

2. Humans versus nature: our long and destructive journey

From an article by Phoebe Weston, guardian website, 25 Nov 2022.

When humans started spreading across the globe they discovered a world full of huge, mythical-sounding mammals called “megafauna”, but by the end of the Pleistocene, one by one, these large animals had disappeared. There is no smoking gun and evidence from ancient crime scenes is – unsurprisingly – patchy. But what investigators have learned suggests a prime suspect: humans.

Take the case of Genyornis, one of the world’s heaviest birds, which was more than 2 metres tall and weighed in excess of 200kg. It lived in Australia until, along with many other megafauna, it went extinct 50,000 years ago. In North America, giant beavers weighing the same as a fridge and an armadillo-like creature called a glyptodon, which was the size of a small car, existed until about 12,000 years ago, when they, too, went extinct. In all, more than 178 species of the world’s largest mammals are estimated to have been driven to extinction between 52,000 and 9,000BC.

For a long time, these extinctions were thought to be linked to natural changes in the environment – until 1966, when palaeontologist Paul S Martin put forward his controversial “overkill hypothesis” that humans were responsible for the extinctions of megafauna, destroying the romantic vision of early humans living in harmony with nature.

Although the debate is far from settled, it appears ancient humans took thousands of years to wipe out species in a way modern humans would do in decades. Fast forward to today and we are not just killing megafauna but destroying whole landscapes, often in just a few years. Farming is the primary driver of destruction and, of all mammals on Earth, 96% are either livestock or humans. The UN estimates as many as one million plant and animal species are at risk of extinction.

After the spread of farming and significant population increases, it was European expansion that would be the next big blow to the planet’s biodiversity. While indigenous peoples across the world lived mostly within the limits set by nature, recognising their dependency on it and protecting it, while hunting to survive, that was about to change. Spanish explorers and settlers arrived in central and southern America in the 15th and 16th centuries. Their arrival heralded the displacement, persecution and killing of indigenous peoples. Today, indigenous people make up just 6% of the world’s population but protect 80% of the planet’s biodiversity.

In the 18th century, one of the most significant missions to understand the diversity of life on Earth was that of the Swedish natural philosopher Carl Linnaeus. He is known as the “father of taxonomy”, naming more than 12,000 species of plants and animals. His *Systema Naturae*, published in 1735, still shapes how we classify flora and fauna today.

The 18th century was also when realisation that humans were having big local impacts on the environment increased. At the end of the century, the explorer Alexander von Humboldt was writing at a time when nature was generally seen as something that humans had to control, but he saw that it was humans who had the power to damage ecosystems through activities such as deforestation, mining and water extraction.

His work was a great inspiration for Charles Darwin. The British naturalist did not use the term biodiversity (which wouldn't be coined for another 150 years) but he had worked out a key premise of it – that all species are linked and can be traced back to a single origin, as most notably laid out in On the Origin of Species, published in 1859. In 1881, Darwin published a book about earthworms in which he showed how they aerate the soil, breaking down organic matter into nutrients that can be used by plants. He proved agriculture – and, therefore, our food supply – is heavily dependent on the amount of worms that we have.

Neither Humboldt nor Darwin were activists, unlike Darwin's collaborator, Alfred Wallace. In his book Island Life, published in 1880, Wallace criticised the "reckless destruction of forests, and with them of countless species of plants and animals".

European scientists' interest in the diversity of life peaked in the Victorian era. Great natural history museums are testament to this excitement of discovery – they wanted to show off the exotic animals and plants collected from all over the British empire to the public at home. For the first time, they began to understand the immense diversity of the natural world and that humans were destroying it.

In the 20th century, a series of natural crises made people more aware nature was under threat, as the planet started being damaged at a faster rate than ever before. The "roaring 20s" gave way to the "dirty 30s" with a decade of dust storms in the US and south-east Australia. In 1935, the dramatic dust clouds of the American midwest loomed over New York and left three-quarters of western states parched. They were caused by a combination of extreme weather – heatwaves and drought – and unsustainable farming practices, which replaced native prairie vegetation.

Ecologist Francis Ratcliffe was sent from London in 1929 to find out more about what was going on in Australia and later wrote Flying Fox and Drifting Sand. He described soil erosion as a "creeping mortal sickness" and said the only solution was to reduce the number of farmers in the area. In response to his reports, soil conservation bodies were created in New South Wales in 1938 and Victoria in 1940.

After the second world war, amateur naturalists started documenting a decline in birds and butterflies. In the US, populations of the bald eagle – the national bird – were rapidly falling. Synthetic pesticides developed during the war, including DDT (dichloro-diphenyl-trichloroethane), used to prevent insect-borne diseases such as typhoid and malaria, were identified as the culprits as more insecticides were used in the push to intensify agriculture.

But it was probably not until the publication of Rachel Carson's Silent Spring in 1962 that the wider public began to understand the implications of the loss of nature. She wrote about how DDT and other chemicals were damaging ecosystems, killing

insects and birds and eventually reaching humans. Immediately there was great public interest. She was sued by American chemical giants who launched a publicity campaign that criticised her for being an unmarried, hysterical and unscientific woman who kept cats and loved birds.

In 1972, DDT was banned in the US, and today a ban on its use in agriculture is worldwide. Carson's book led to numerous laws being passed to protect the environment as well as the creation of the US Environmental Protection Agency. In 1969, Friends of the Earth was set up in the US and two years later Greenpeace was founded in Canada. Awareness about the environment was at an all-time high.

Meanwhile, in the UK, a popular TV presenter was seen lying down beside a mountain gorilla, called Poppy, in Rwanda. It was 1979 and the presenter was David Attenborough, whose series Life on Earth was watched by 25 million people. For the first time, huge swathes of the public witnessed lifeforms they never could have imagined and learned about wildlife far away.

A trio of biodiversity researchers – Richard Leakey, Edward O Wilson and Thomas Lovejoy, were key in driving forward an awareness about threats to the natural world. Lovejoy persuaded famous people such as Tom Cruise to go the Amazon to raise awareness of its immense diversity and why it needs protection. The term "biological diversity" appears to have been used for the first time in 1916 in an article by J Arthur Harris titled The Variable Desert, but it was not until 1980 that Lovejoy used the term in scientific work. It was picked up rapidly and contracted to biodiversity.

In 1986, nine prominent US scientists attending the National Academy of Sciences forum on biodiversity warned that species loss was the most serious challenge facing the world, "second only to the threat of thermonuclear war".

According to Libby Robin, emeritus professor at the Australian National University, "Climate scientists (physicists) elsewhere were starting to be concerned about carbon/global warming but this emphasis came later in the public mind, particularly with James Hansen's message to the American Congress at the height of the hot 'greenhouse' summer in 1988."

One of the first and most important organisations set up to try to protect biodiversity was the International Union for Conservation of Nature (IUCN). It was founded in the French town of Fontainebleau in 1948, and supported the creation of international law to protect the planet's wildlife. Today, the IUCN is a leading force in shaping international conventions, developing rules and principles for conservation and management of ecosystems. It first established its Red List of Threatened Species in 1964, as a way to mobilise funding and experts to tackle extinction threats. It continues to be the global authority on biodiversity loss, regularly releasing reports and updates.

The IUCN helped push through legislation to tackle wildlife loss by creating the first draft of what would become the UN's convention on biological diversity (CBD).

The birth of the CBD was at the Rio conference in 1992, when the UN created the conventions on climate change (IPCC), biodiversity (CBD) and desertification

(UNCCD). The three goals of the CBD are: the preservation of biological diversity; the sustainable use of its components; and fair and equitable sharing of the benefits of genetic resources. Every 10 years, it aims to set targets on biodiversity for the following decade. But the targets are not legally binding and the world failed to meet a single one of the 20 set out at Aichi in Japan in 2010.

An orangutan seeks refuge from bulldozers as they destroy the forest in Ketapang district, West Borneo.
Photograph: International Animal Rescue

The UN biodiversity conference Cop15 will be held for two weeks in Montreal, Canada, from 7 December. The meeting comes weeks after the Cop27 climate meeting in Egypt. Ever since the Rio summit, biodiversity has taken second place to the climate on the international stage. The climate crisis generally gets more media attention because flooding and fires make headline news, whereas biodiversity loss is harder to see.

From hunting huge mammals to extinction to poisoning birdlife with pesticides, humans have treated nature as an inexhaustible resource for too long. Environmentalists, indigenous peoples and scientists have been sounding the alarm about the biodiversity crisis for more than half a century, and yet no meaningful action has been taken. Much has already been lost, but there is still lots to play for. Cop15 is an opportunity to start to change the narrative.

3. Arctic permafrost

From an article by Katie Hunt, CNN, November 12, 2022

The vast amount of carbon stored in the northernmost reaches of our planet is an overlooked and underestimated driver of climate crisis. The frozen ground holds an estimated 1,700 billion metric tons of carbon – roughly 51 times the amount of carbon the world released as fossil fuel emissions in 2019, according to NASA. It may already be emitting as much greenhouse gas as Japan.

Permafrost thaw gets less attention than the headline-hogging shrinking of glaciers and ice sheets, but scientists said that needs to change — and fast. “Permafrost is a buried phenomenon. You don’t see it. It’s covered by vegetation and soil,” said Merritt Turetsky, director of the Institute of Arctic and Alpine Research at the University of Colorado Boulder.

Warmer summers — the Arctic is warming four times faster than the global average — have weakened and deepened the top or active layer of permafrost, which unfreezes in summer and freezes in winter. This thawing is waking up the microbes in the soil that feast on organic matter, allowing methane and carbon dioxide to escape from the soil and into the atmosphere. It can also open pathways for methane to rise up from reservoirs deep in the earth.

“Permafrost has been basically serving as Earth’s freezer for ancient biomass,” Turetsky said. “When those creatures and organisms died, their biomass became incorporated into these frozen soil layers and then was preserved over time.” As permafrost thaws, often in complex ways that aren’t clearly understood, that freezer lid is cranking open, and scientists such as Turetsky are doubling efforts to understand how these changes will play out.

Climate wild card

Permafrost is a particularly unpredictable wild card in the climate crisis because it’s not yet clear whether carbon emissions from permafrost will be a relative drop in the bucket or a devastating addition. The latest estimates suggest that the magnitude of carbon emissions from permafrost by the end of this century could be equal to or bigger than present-day emissions from major fossil fuel-emitting nations.

Brendan Rogers, an associate scientist at the Woodwell Climate Research Center in Massachusetts described the permafrost as a sleeping giant whose impact wasn’t yet clear. “We’re just talking about a massive amount of carbon. We don’t expect all of it to thaw … because some of it is very deep and would take hundreds or thousands of years,” Rogers said. “But even if a small fraction of that does get admitted to the atmosphere, that’s a big deal.”

Projections of cumulative permafrost carbon emissions from 2022 through 2100 range from 99 gigatons to 550 gigatons. By comparison, the United States currently emits 368 gigatons of carbon, according to a paper published in September in the journal Environmental Research Letters.

Not all climate change models that policymakers use to make their already grim predictions include projected emissions from permafrost thaw, and those that do assume it will be gradual, Rogers said. He and other scientists are concerned about the prevalence of abrupt or rapid thawing in permafrost regions, which has the power to shock the landscape into releasing far more carbon than with gradual top-down warming alone.

The traditional view of permafrost thaw is that it’s a process that exposes layers slowly, but “abrupt thaw” is exposing deep permafrost layers more quickly in a number of ways. For example, Big Trail Lake in Alaska, a recently formed lake, belches bubbles of methane — a potent greenhouse gas, which comes from thawing permafrost below the lake water. The methane can stop such lakes from refreezing in winter, exposing the deeper permafrost to warmer temperatures and degradation.

Rapid thawing of the permafrost also happens in the wake of intense wildfires that have swept across parts of Siberia in recent years. Sometimes these blazes

smolder underground for months, long after flames above ground have been extinguished, earning them the nickname zombie fires. “The fires themselves will burn part of the active layer (of permafrost) combusting the soil and releasing greenhouses gases like carbon dioxide,” Rogers said. “But that soil that’s been combusted was also insulating, keeping the permafrost cool in summer. Once you get rid of it, you get very quickly much deeper active layers, and that can lead to larger emissions over the following decades.”

Also deeply concerning has been the sudden appearance of around 20 perfectly cylindrical craters in the remote far north of Siberia in the past 10 years. Dozens of meters in diameter, they are thought to be caused by a build-up and explosion of methane — a previously unknown geological phenomenon that surprised many permafrost scientists and could represent a new pathway for methane previously contained deep within the earth to escape.

War a ‘disaster for our scientific enterprise’

A lack of monitoring and data on the behaviour of permafrost, which covers 15% of the exposed land surface of the Northern Hemisphere, means scientists still only have a patchwork, localized understanding of rapid thaw, how it contributes to global warming and affects people living in permafrost regions.

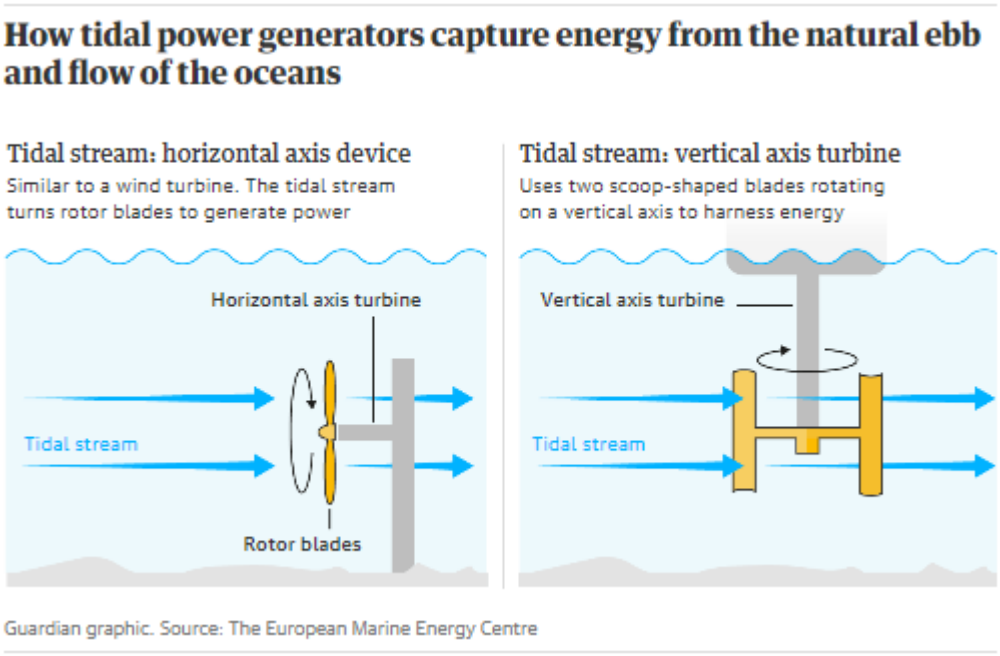
Rogers is part of a new $41 million initiative, funded by a group of billionaires and called the Audacious Project, to understand permafrost thaw. It aims to coordinate a pan-Arctic carbon monitoring network to fill in some of the data gaps that have made it difficult to incorporate permafrost thaw emissions into climate targets.

The project’s first carbon flux tower, which tracks the flow of methane and carbon dioxide from the ground to the atmosphere, was installed this summer in Churchill, Manitoba. However, plans to install similar monitoring stations in Siberia are in disarray as a result of Russia’s invasion of Ukraine. The European and US scientists working in this field can no longer interact with their counterparts at Russian institutions. The small community of specialists all over the world have been split into disconnected political groups, but the problems are global and connected.

4.UK tidal-stream energy development

From an article by Tom Wall, Guardian website, 23 Nov 2022

For decades the immense practical difficulties of harnessing the powerful tides flowing around Britain’s shorelines have put off investors and government officials searching for big renewable energy sources. But as the costs of deploying turbines in tidal streams fall, more and more people are seeing the potential in an energy source that creates energy as the tides ebb and flow at predictable hours every day – energy that is renewable but not intermittent.



The cost of generating power from tidal streams has fallen by 40% since 2018 – and a report published last month by a government-backed research centre, Offshore Marine Catapult, forecasts prices could fall below nuclear energy in little over a decade, with one-megawatt hour of power due to cost as little as £78 by 2035 compared with £92.50 for the new Hinkley Point C power plant.

Simon Cheeseman, the report's author, argues tidal stream energy is at the "point of commercialisation" as companies are keen to scale up production and deployment. But he says the sector still needs careful nurturing to ensure it follows the successful trajectory of offshore wind, which in 11 years has gone from generating only enough energy for 4% of British homes to generating enough for 33% of British homes. "In the early days of offshore wind, you had strong government support. This is the perfect blueprint for tidal stream energy," he says. "There is no reason tidal can't follow that same route."

Orbital Marine, which operates what it says are the world's most powerful turbines below a plane-like floating platform near Orkney, has secured government funding to deploy three more floating turbines next year. Each platform can generate enough power for 2,000 homes and creates an estimated 100 jobs, according to the firm. "We want this to kickstart a real phase of change for us. We want to start manufacturing consistently and pull in more commercial investment," says Andrew Scott, the company's chief executive. "This is the first time in my 20 years in marine renewables that we've got a genuine chance of making tidal stream energy work commercially."

Another pioneering developer, Simec Atlantis Energy, is planning to install up to 56 turbines on the seabed at the northernmost tip of Scotland by 2027. "We've got the world's largest tidal stream project off the coast of Caithness – 70% of the global tidal output has come from that site," says Sean Parsons, the company's external affairs director. "We've just won a government contract to expand that site from what

is now 6 megawatts to take it all the way up to 34 megawatts – enough power for 68,000 homes. It's tidal at scale."

Unlike tidal barrages and tidal lagoons, which involve mounting turbines in sea walls, tidal stream turbines are lowered directly into strong tides out at sea. The challenges of installing and testing turbines in sometimes turbulent waters have made it far more costly than building wind and solar farms. But developers have been steadily refining their designs and driving down costs, with turbines becoming more powerful and easier to deploy at sea. "We are learning by doing: it used to take two days to connect up devices in the water but now it takes just two hours," says Cheeseman.

"Offshore wind and solar are intermittent. But we know for certain when the tides come in and go out," says Cheeseman. "It provides the energy buffer that you need in a system that will increasingly depend on irregular power."

Government support, however, has been patchy. But at the end of last year the ministers allocated £20m worth of funding to the sector, under the government's "contract for difference" scheme, which provides a guaranteed price for renewable energy. Four commercial-scale tidal energy bids, including two from Orbital Marine and one from Simec Atlantis, were successful. These projects are expected to deliver a near fivefold increase in the energy from British tidal power by 2027, upping the amount generated rising from 10.4 megawatts to 51.2 megawatts.

The government's renewed faith in the sector is already attracting a surprising range of private-sector investors. "It was almost an impossible job to raise investment but since [the funding announcement] we've managed to get investment from major oil and gas providers and we've got an active inbound interest in equity investment right now," says Scott.

Nevertheless, problems remain. Unlike offshore wind, there is no official target for marine energy including tidal stream power, which is needed to drive investment. And the process of getting approval for underwater turbines can be extremely long-winded. It has taken Nova Innovation two-and-a-half years from gaining the seabed lease to being ready to install a turbine in Nova Scotia, Canada. But in the UK it can take more than twice as long to complete a tidal stream energy project, with everything from environmental impact assessments to grid connection causing delays.

5.Boosting wind farm energy output

From an article by Michelle Lewis, Electrek, Aug 12, 2022

Wind turbines are controlled as freestanding units and only maximize their own power production, but the wake of each wind turbine impacts each other.

MIT's Esther and Harold E. Edgerton assistant professor of civil and environmental engineering Michael F. Howland explains:

- Essentially all existing utility-scale turbines are controlled 'greedily' and independently.

- From a flow-physics standpoint, putting wind turbines close together in wind farms is often the worst thing you could do. The ideal approach to maximize total energy production would be to put them as far apart as possible.

But if wind turbines are spread out, that increases associated costs, so it's not a practical solution.

Howland led a team of scientists supported by MIT and Siemens Gamesa Renewable Energy who published a new study yesterday (11 August) in the journal *Nature Energy*. The researchers found – based on real-world tests at a utility-scale wind farm in India – that a wind farm's energy output can be increased if individual turbines are optimized and the wind flow is modelled collectively.

MIT News explains the team's findings:

- Today, each turbine constantly senses the incoming wind direction and speed and uses its internal control software to adjust its yaw (vertical axis) angle position to align as closely as possible to the wind. But in the new system, for example, the team has found that by turning one turbine just slightly away from its own maximum output position — perhaps 20 degrees away from its individual peak output angle — the resulting increase in power output from one or more downwind units will more than make up for the slight reduction in output from the first unit. By using a centralized control system that takes all of these interactions into account, the collection of turbines was operated at power output levels that were as much as 32% higher under some conditions.

- Howland estimates that, translated to the world's existing fleet of wind turbines, a 1.2% overall energy improvement would produce more than 31 terawatt-hours of additional electricity per year, approximately equivalent to installing an extra 3,600 wind turbines at no cost. This would translate into some $950 million in extra revenue for the wind farm operators per year, he says.

The algorithm has the potential to be useful in any geographical location, and new hardware installation is not required to implement this efficiency improvement; it just requires making a software change. And reducing wake losses means turbines can be clustered even more closely together, thus saving on land or sea footprints.

Ross Rutherford

ESR Newsletter Editor

1 December 2022

Appendix: US DoE Biofuel Innovation Booklet, April 2022

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Biofuel Innovation: Clean Energy Solutions, Ready Today

To combat climate change, the United States intends to build a 100% clean energy economy and reach net-zero emissions by 2050. The United States can employ innovative biofuel solutions today to help drive the country toward a cleaner energy future.

Innovations in biofuels research are leveraged today in transportation technologies and infrastructure. The clean energy future is enabled by the U.S. Department of Energy (DOE) Bioenergy Technologies Office (BETO) investment of $255 million enacted in Fiscal Year 2021 for biofuels research and development (R&D). With over 300 active R&D projects, BETO initiatives encourage cost-competitive, efficient, and sustainably produced biofuels.

Biofuels can be blended with or completely replace a range of fossil fuels significantly reducing greenhouse gas (GHG) emissions over a 30-year time horizon. One example of this is fuels from energy crops which have significant potential to reduce GHG emissions relative to conventional fuels because feedstocks can be produced using marginal land.[1] These cleaner fuels can power transportation technologies in use today. Furthermore, the pipelines, fueling stations, and other infrastructure that support these technologies can work with biofuels allowing for an easier transition and immediate impact.

A National Renewable Energy Laboratory (NREL) researcher prepares samples in the Analytical Characterization Lab in the Integrated Biorefinery Research Facility (IBRF).
Photo courtesy of Dennis Schroeder, NREL 60925.

Biofuels Support Existing Vehicle Fleets

In the United States, cars and trucks use approximately 54.4 million gallons of diesel fuel annually.[2] A diesel car or truck purchased today will likely be on the road for the next 12 years.[3] Innovative biofuel R&D funded and supported by BETO can reduce life cycle GHG emissions for these existing diesel cars and trucks.

For example, DOE has funded the development and scale-up of T2C-Energy's TRIFTS® process that can take either landfill gas or biogas from an anaerobic digester and turn it into cost effective, carbon neutral/negative renewable diesel. T2C-Energy is currently designing their 1,000,000 gasoline gallon equivalent/year demonstration facility which will utilize over 1,300 standard cubic feet per minute of landfill gas.

Sustainable Aviation Fuels Available Today

According to the International Energy Agency, the aviation sector will account for about 15% of global oil demand growth through 2030 and currently consumes more than 26 billion gallons of jet fuel annually.[4] Airlines make a significant investment every time they purchase a new plane, and the more than 7,500 aircraft currently in service will continue flying for decades. Couple this with the difficulty of electrifying long-range flights.

BETO, along with industry partners like LanzaTech and Virgin Airlines, are researching methods to foster biofuel use for aviation by helping lower cost and increase accessibility. BETO funds DOE national laboratories to conduct applied R&D to reduce cost and risk associated with innovative pathways to sustainable aviation fuels. Some of the R&D efforts include developing catalysts and biocatalysts and upgrading biomass-derived intermediates.

Lower Marine Emissions through Biofuels

Global marine fuel consumption is approximately 87 billion gallons of mostly heavy fuel oil and is expected to double in the next 20 years.[5] Although marine fuels account for just 7% of transportation fuel demand, it accounts for 90% of the transport sector sulfur oxide emissions.[6]

A Cleaner Future Now with Biofuels

Bioenergy is a critical part of a holistic approach to address a clean energy future with solutions that work today. Whether land, air, or marine transport, BETO supports research to enable U.S. industry to drive down costs for consumers, and lower emissions for everyone.

1 epa.gov/environmental-economics/economics-biofuels
2 go.usa.gov/xzckh
3 autonews.com/article/20161122/RETAIL05/161129973/average-age-of-vehicles-on-road-hits-11-6-years
4 eia.gov/state/seds/data.php?incfile=/state/seds/sep_fuel/html/fuel_jf.html&sid=US
5 nrel.gov/docs/fy19osti/74678.pdf
6 afpm.org/newsroom/blog/us-marine-fuel-makes-shipping-cleaner

BETO supports R&D into cost-competitive, efficient, and sustainably produced biofuels for the auto, airline, and shipping industries.
Photos courtesy of iStock (left to right) 1307086567, 499098808, and 591986620.

Along with lowering maritime GHG emissions, biofuels can eliminate sulfur oxide emissions, helping maritime shippers comply with IMO 2020, the rule limiting sulfur in ship fuel oil.[7] Previously, BETO commissioned a multi-laboratory effort to outline the opportunities and challenges associated with using biofuels on marine vessels. This effort resulted in BETO's *2019 R&D State of Technology* report and serves as a basis for BETO's efforts to address marine biofuel feasibility and define opportunities.[8]

Biofuels Support Existing Fuel Infrastructure

U.S. fueling infrastructure contains more than 100,000 vehicle gas stations that are served by well-established regional refineries, and fuel storage and distribution networks.[9] These systems have been in place for decades and have withstood times of crisis during natural disasters, trade disruptions, and even a global pandemic.

Biofuels are compatible with this massive fueling infrastructure. BETO endeavors to strengthen this infrastructure by working with industry to encourage co-location of bioenergy processing facilities and the reuse of equipment and utilities to lower upfront capital costs and reduce long-term operating costs.[10] Recent analysis suggests that refinery integration could lead to a $.50/gasoline gallon equivalent reduction in the cost of biofuel production.[11]

BETO has supported several collaborative projects between the national laboratories and industry to develop data to help close several gaps and risks associated with refinery integration. One of these projects involved NREL, Petrobras, and other partners to successfully co-process pine-based raw bio-oil with petroleum-based fuel to optimize feed options.[12] Concerning existing infrastructure and biofuels, DOE has provided a handbook for dispensing E85 and other ethanol-gasoline blends from existing gas stations.[13] ■

About the Bioenergy Technologies Office

BETO supports research, development, and demonstration to enable the sustainable use of domestic biomass and waste resources for the production of biofuels and bioproducts. BETO's overall goals are designed to:

- Lower costs and reduce technology risks for production of biofuels and bioproducts
- Improve environmental benefits of bioenergy production
- Reduce greenhouse gas emissions from the transportation, industrial, and agricultural sectors to address the climate crisis
- Support the scale-up of sustainable, low-carbon biofuel production technologies
- Create economic opportunities and good-paying jobs in agriculture and manufacturing sectors.

Meeting these goals requires significant and rapid advances in technology development and innovation across the entire biomass-to-bioenergy supply chain.

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
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For more information, visit:
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7 statista.com/statistics/525107/number-of-gasoline-stations-in-the-united-states
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