NICE Future
Nuclear Innovation: Clean Energy Future

Climate Solution Fact Sheet: 4 Solutions to Achieve Net Zero by 2050

November 2023

Achieving Net Zero will be difficult even if we use all the zero-carbon energy technologies currently available. The challenge is not only to build enough clean electricity generation to power the world without associated environmental emissions, but to do so quickly while also building the infrastructure required to decarbonize end-use sectors such as heat, industry, and transport.

This Nuclear Innovation Clean Energy Future Initiative's Research the Impacts on Social Equity and Economic Empowerment (RISE^3) campaign[1] fact sheet describes four potential solutions that can help de-risk and accelerate the path to Net Zero.[2]

1. Repowering Coal

Repowering coal could offer a fast, large-scale, low-risk, and equitable contribution to decarbonizing the world's power generation.

Coal plants currently produce almost one-third of total global carbon emissions.[3] Repowering the existing coal plant infrastructure is therefore the largest single carbon abatement opportunity on the planet. Repowering coal plants could also enable a just transition to clean energy by sustaining the jobs and local tax revenues associated with existing coal plants and providing larger social, economic, and environmental benefits associated with continued reliable and flexible electricity generation, as well as the continued use of existing infrastructure including transmission lines—without emissions.

Replacing coal-fired boilers at existing coal plants with carbon-free advanced heat sources (small modular nuclear reactors, including small modular and advanced fission and fusion reactors) means that these power plants can generate carbon-free electricity rather than carbon-intensive electricity. This would quickly transform coal-fired power plants from polluting liabilities facing an uncertain future into jewels of the new clean energy transition—an important part of the massive and pressing infrastructure buildout needed to address climate change.

Converting 5,000–7,000 coal plant units globally between 2030 and 2050 (250–350 per year) will require a redesigned delivery model to meet this rate of deployment. To be successful, the deployment model has to de-risk the construction process: the riskiest part of a project. Purpose-built automated tools can enable rapid, repeatable, and reliable project assessments to de-risk and facilitate initiation and completion of repowering projects.

Repurposing the majority of existing coal plant sites and infrastructure, including transmission, and maintaining the workforce employed today, would dramatically reduce the investments and effort required to site, plan, build, and connect new infrastructure (Figure 1 shows a rendering of a repowered 1,200 MWe plant[4]).

What is more, rather than closing these carbon-intensive and polluting power plants, repowering them with advanced heat sources would retain many permanent high-quality local jobs. Overall, repowered coal plants could reduce many of the negative impacts on communities to help enable public and political support for a just energy transition.

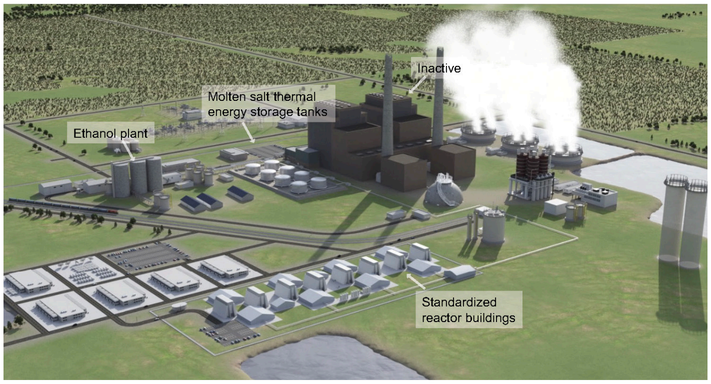

Figure 1. Repowering coal case study: two-steam-unit, 1,200 MWe plant[5]

2. Flexible Generation

New advanced heat sources can do more than just provide reliable, clean electricity. They can offer added flexibility for power grids, decarbonize heating and industrial processes, and produce low-cost hydrogen and synthetic fuels. A helpful feature of some advanced designs is the separation of the heat source (reactor)

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[1] *NICE Future initiative RISE^3 campaign*

[2] *These are described in more detail in LucidCatalyst (2022), Beautiful Nuclear.*

[3] *Global Coal Plant Tracker, Global Energy Monitor, February 2022.*

[4] *Terra Praxis, Climate Solution Profile: Repowering the Global Coal Fleet by 2050, March 2022.*

[5] *Rendering by Virtual Experience Company and features designs by Bryden Wood for Terra Praxis' Repowering Coal Project.*

from the turbine-generator that produces the electricity (called the power island) via a thermal energy storage and transfer system. Thermal energy storage systems allow the heat sources to operate continuously at full capacity, while charging the thermal 'battery' energy storage system. This enables the plant to operate flexibly, much like hydro or natural gas plants, enabling higher penetrations of variable renewable energy, and in support of lower overall system costs and emissions.

Decoupling the heat (nuclear) island from the power island creates other benefits, such as a smaller, more focused scope for nuclear regulatory oversight, lower relative costs (and construction risks) for the turbine island and balance of plant, a shorter project schedule by leveraging opportunities for parallel construction, and greater overall certainty of cost and schedule.

Flexible advanced reactors—in combination with wind, solar, and hydro—can therefore make a substantial contribution to building reliable, responsive, affordable, and clean energy systems supplying clean dispatchable power generating capacity.

3. Hydrogen Cogeneration — Electricity, Heat & Hydrogen

Currently, 65% of the energy that nuclear power plants produce ends up in the cooling water. Cogeneration, or the production of both electricity and heat, can enable more efficient and flexible use of power plants.

While a normal power plant can usually turn 35% of the heat it produces into useful energy (electricity), a cogeneration plant can utilize well over 80% of the heat it produces—supplying a combination of electricity, high quality process steam, and low-quality heat for district heating or desalination. For heat-only plants and applications, the total efficiency is almost 100%. Cogeneration increases flexibility, as it can allow a plant to switch seamlessly between electricity and other applications.

Cogeneration of power and heat, or power and hydrogen for example, where hydrogen is an intermediate product, can increase the overall efficiency and economics of nuclear plants while decarbonizing heat that can be provided to industry and other heat users. Heat production in turn has the opportunity to be used for other products.

Low-Temperature District Heating

Low-temperature district heating (80 – 120°C) is a form of cogeneration with only a relatively small effect on electricity generation. A lot of valuable heat that is otherwise rejected to the cooling system can instead be delivered to homes and businesses. Space heating and hot water represent a surprisingly large share of energy use (up to one-third in Europe). District heating offers one solution to reduce carbon emissions by providing space and water heating (and potentially cooling) for a city, town, or district from a large central heating source through a network of pipelines.

Hydrogen and Synfuels

Hydrogen-based synthetic fuels (synfuels) are economically promising 'drop-in' alternatives for decarbonizing hard-to-abate sectors such as industry and heavy transport. Hydrogen-based fuels are made by combining hydrogen separated from water with carbon extracted from the atmosphere using carbon capture technology. Hydrogen derived from water electrolysis is emissions-free and entirely renewable, as it is returned to water upon combustion. Today, hydrogen is used in oil refining and ammonia-manufacturing, but it is primarily produced using fossil fuels in a process called steam methane reforming, resulting in significant emissions. If clean hydrogen were used to produce synthetic fuels (hydrocarbons or ammonia) on a large scale, these could replace fossil fuels in many sectors that are difficult to electrify, such as aviation and shipping.[6]

However, getting to costs below $1/kg hydrogen[7] within this decade will be a major challenge. The next section describes how new delivery models for advanced heat sources could help us achieve these very low hydrogen production costs.

4. Dedicated Hydrogen/Synfuels Production[8]

Two strategies are presented here for large-scale low-cost hydrogen and synthetic fuels production with nuclear energy. The first 'brings the factory to the project'. The second 'brings the project to the factory'.

The Hydrogen Gigafactory

The refinery-scale Hydrogen Gigafactory is an 'energy park'[9] combined with an integrated manufacturing facility. The strategy is to 'bring the factory to the project' to supply the needed heat and power, equipment, and facilities that can streamline manufacturing, operations, and maintenance. One Gigafactory can house dozens of heat sources, which can be manufactured on site. Each reactor could produce hundreds of megawatts of capacity used for hydrogen production.

For countries developing such refinery-scale facilities, the Hydrogen Gigafactory represents an opportunity to establish a world-class domestic supply chain capability, the potential to export

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[6] *Kirsty Gogan and Eric Ingersoll, "Missing Link to a Livable Climate: How Hydrogen-Enabled Synthetic Fuels Can Help Deliver the Paris Goals," September 2020*

[7] *https://www.energy.gov/eere/fuelcells/hydrogen-shot*

[8] *Ibid.*

[9] *Several Energy Parks are being planned, some examples are: Energy Park Bad Lauchstädt and the North Sea Energy Park*

synthetic fuels, and the potential to achieve affordable decarbonization. Simplified heat source designs and factory setting minimize installation labor costs and enable the application of fast, high quality manufacturing techniques; streamlined licensing is enabled by reusable designs and repeatable processes in a standardized factory, managed by fixed teams, operating continuously enabling the Hydrogen Gigafactory to deliver large quantities of very low-cost hydrogen, eventually enabling a path to ultra-low-cost hydrogen at the target price of less than $1/kg (Figure 2).

Figure 2. Render of a Hydrogen Gigafactory

Shipyard-Manufactured Production Platforms

The second strategy for producing cost-competitive hydrogen is the shipyard-manufactured production platform, which 'brings the project to the factory'. This route builds hydrogen production facilities in the form of a ship—at a shipyard. Such ships would be called floating production, storage, and offloading (FPSO) facilities. The proposed form uses onboard high-temperature nuclear reactors to generate heat and electricity, which are integrated with onboard hydrogen production equipment.

The hydrogen produced on the ship can be used to make synthetic hydrocarbons or ammonia, which can be used to fuel marine vessels or transported for other uses. The key innovation here is to transform the currently unproductive, risky, and expensive construction-at-place method of delivering facilities to a highly productive shipyard environment.

Floating production ships come with the benefit of offshore siting (Figure 3), adding flexibility. This 'bring the project to the factory' approach dramatically improves productivity; adds innovation, modularity, and state-of-the-art manufacturing methods; lowers costs; and makes quality control easier due to streamlined factory production process, creating easy to manage quality checkpoints at different stages while maintaining strict regulation of nuclear power components. Currently, idle shipyard capacity is high around the world. These idle shipyards could provide critical economic development by serving as the basis of a new industry that attracts investment, boosts employment, generates clean energy, and contributes to decarbonization. FPSOs close to shore could also be configured to produce electricity and desalinated water—enabling low-cost and low-carbon energy services for countries that still lack the necessary institutions and expertise to have domestic nuclear programs.

Figure 3. Conceptual ammonia bunker offloading ammonia from a production platform.

Decarbonizing Oil & Gas

The rapid achievement of low-cost hydrogen via these innovative delivery models could accelerate deep decarbonization across sectors currently using oil and gas. By 2050, low-cost clean hydrogen could help avoid cumulative emissions on a scale measured in the hundreds of gigatons, equal to years, if not a decade's, worth of current global emissions.

The FPSO model could also be used to produce other liquid fuels, including jet fuel, gasoline, and diesel. These scenarios utilize existing and proven chemical technologies and production processes; no further discovery or innovation is needed, although some technologies, such as high temperature steam electrolysis, would need to be brought to commercial scale. The resulting commodities would be drop-in substitutes—not requiring major changes to existing supply chain infrastructure, regulations, or behavior.

To Conclude

Current and emerging advanced nuclear reactors can do more than just provide reliable, clean electricity. They can offer added flexibility for power grids, decarbonize heating and industrial processes, as well as produce low-cost hydrogen and synthetic fuels. The next decade will be critical for dramatically increasing clean energy generating capacity by applying innovative deployment models such as the ones described above.

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