

# Carbon Free Future (CFF)

A national industrial strategy for a hydrogen-based, fossil-free Britain.

## **The Elevator Pitch:**

*"CFF is a national infrastructure program that turns the UK coastline into a clean energy backbone using 25 identical mega-sites. By combining British-made SMRs with industrial-scale hydrogen production, we create a 'national safety valve' that provides 24/7 baseload power to the grid while decarbonizing the hard-to-reach sectors like heavy industry, shipping, and home heating. It's not just a power plan; it's a 25-year industrial mission to secure UK energy sovereignty and high-skill jobs for generations."*

## Executive Summary (For Busy People)

- **What CFF is:** A network of 25 coastal mega-sites around the UK, each with seven small modular reactors (SMRs), large electrolyzers, desalination, and industrial facilities. Together, they form a new backbone for a hydrogen-based, fossil-free Britain.
- **Main product:** Hydrogen at truly industrial scale, made from clean nuclear power. Electricity to the grid is important, but hydrogen is the primary output, used for heating, transport, industry and fuels.
- **More than power stations:** Each site is a "sea-to-street" factory: seawater and uranium in; hydrogen, oxygen, desalinated water, minerals and electricity out. The hubs anchor new coastal industries and jobs.
- **Why seven SMRs per site:** Multiple smaller units give resilience (no single massive trip), a strong fleet learning effect, and fine-grained control over how much power goes to hydrogen versus the grid.
- **British kit and workers:** The aim is to keep as much of the spend as possible in the UK, repurpose North Sea and heavy-industry skills through a national skills passport, and turn CFF into an exportable package.
- **Hydrogen-heavy future:** By 2055, around 70% of heating is via hydrogen boilers, 70% of light vehicles are hydrogen fuel-cell, and heavy transport and high-temperature industry run on hydrogen or hydrogen-derived fuels.
- **What that means for the grid:** The electricity grid still matters, but it no longer has to do everything. Winter peaks are smaller and easier to manage because hydrogen carries much of the heating and transport load.
- **Dynamic grid support:** In normal times, most SMR output runs electrolyzers. When the grid is tight, CFF sites can ramp electrolyzers down and divert power to the grid, releasing up to hundreds of megawatts per site without touching the reactors.
- **Byproducts and circular economy:** Large volumes of oxygen are sold into medical and industrial markets; desalination brines become sources of lithium and other minerals. Each site supports a wider circular economy.

- **The big picture:** CFF is not just a nuclear plan. It is a national industrial strategy: clean baseload power, mass hydrogen production, grid balancing, new coastal industries, and a long-term future for skilled workers as the UK leaves fossil fuels behind.

## 1. What CFF Is, In Plain English

Carbon Free Future (CFF) is a plan to rebuild the United Kingdom's energy system around a new kind of coastal infrastructure. Instead of a handful of giant nuclear plants and a patchwork of gas stations, the country would build a fleet of identical coastal hubs. Each hub combines small modular reactors (SMRs), large-scale electrolysers, desalination, hydrogen processing and industrial facilities. Together, these hubs provide the backbone for a hydrogen-based, fossil-free Britain.

### Key facts in one place

- **25 coastal mega-sites** around the UK.
- Each site has **7 x 470 MWe SMRs**, roughly **3.3 GWe** per site.
- Full build-out gives around **82 GWe of nuclear capacity** from CFF alone.
- Most of that power runs **electrolysers to make hydrogen**. A smaller portion goes straight to the grid.
- Hydrogen is then used to heat homes, run industry, power heavy transport, and make synthetic fuels.
- In grid emergencies, each site can quickly divert some of its output away from hydrogen and back into the grid.

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## 2. How a Single CFF Site Works

Think of one CFF site as a "sea-to-street" factory. It takes in seawater and uranium fuel. It sends out hydrogen, oxygen, desalinated water, critical minerals, and, when needed, electricity.

### 2.1 The core components

- **Seven SMRs** produce steady, low-carbon electricity day and night.
- **Desalination units** take in seawater and produce high-purity water.
- **Electrolysers** split water into hydrogen and oxygen.
- **Hydrogen processing** compresses, liquefies or converts hydrogen into ammonia or synthetic fuels.
- **Export infrastructure** sends hydrogen and products out by pipeline, ship, rail and road.
- **Grid connection** allows part of the nuclear output to go directly into the electricity system.

### 2.2 The 3-mile separation ring

Each site is laid out with a deliberate buffer: a three-mile ring between the nuclear island and the hydrogen-processing area. The reactors sit in a secure inner zone; hydrogen production, storage and loading happen in an outer industrial zone. This keeps hazardous inventories

physically separated from the reactors and gives regulators and the public a clear, conservative safety case.

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### **3. More Than Just Power Generation**

CFF is often described as a nuclear programme, but that understates what it is trying to do. It is really a national industrial strategy wrapped around clean energy. Each coastal hub is designed to support a whole ecosystem of industries, with multiple revenue streams.

#### **3.1 Hydrogen as the main product**

The primary output of a CFF site is hydrogen. This is not hydrogen in tiny demonstration volumes. At full scale, a single mega-site can produce well over a thousand tonnes of hydrogen a day. Across all 25 sites, output runs into many millions of tonnes of hydrogen per year – enough to decarbonise large parts of heat, transport and industry.

#### **3.2 Valuable byproducts: oxygen and minerals**

Electrolysis always produces oxygen alongside hydrogen. At CFF scales, this oxygen is produced in huge volumes—tens of thousands of tonnes per day across the fleet. Rather than just venting it, the plan is to sell it into medical, industrial and environmental markets. Oxygen can support hospitals, wastewater treatment, steelmaking, glass production and even intensive aquaculture.

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### **4. How CFF Helps the Grid in Times of Need**

The most important difference between CFF and a conventional nuclear plant is how it connects to the electricity grid. A traditional large reactor, like Hinkley Point C, pushes power into the grid and tries to stay online all the time. It can ramp somewhat, but big swings are slow and expensive. CFF sites keep the reactors steady and flex the load beneath them instead.

#### **4.1 Electrolysers as a controllable load**

In a normal year, a typical CFF site will dedicate most of its SMR output to running electrolysers. That might mean around 2.3 to 2.9 GW of electrical power going into hydrogen production at each site, day in, day out.

When the grid is under stress—say a cold, still winter evening with low wind and high heating demand—the system operator can call on CFF to help. The electrolysers at one or more sites are ramped down, freeing up power that can be diverted to the grid through the existing high-capacity grid connection.

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### **5. Why Seven SMRs Per Site Instead of One Huge Reactor**

Choosing seven small reactors per site, instead of a single giant one, is a deliberate design decision. It is about resilience, speed and economics.

## 5.1 Resilience and N+1 security

With seven reactors at a site, losing one unit—whether for maintenance or an unplanned trip—only reduces output by about 14 percent. The site can still produce hydrogen and support the grid with the remaining six. There is no single point whose failure would suddenly remove several gigawatts from the system.

## 5.2 The fleet effect

Seven identical SMRs per site, multiplied across 25 sites, means a fleet of 175 near-identical units. Once the first few are built, engineers, fabricators and constructors learn quickly. Designs, procedures and supply chains stabilise. Costs fall as experience builds. This "fleet effect" is one of the big advantages of modular nuclear compared with one-off mega-projects.

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# 6. Why Use British Kit and British Workers

The CFF concept is not just about technology. It is also about who builds it, who owns it and who benefits from the money spent. The proposal emphasises using British-made equipment wherever possible and a predominantly British workforce.

## 6.1 Keeping value in the domestic economy

The capital investment for a programme of this scale is measured in the hundreds of billions of pounds over several decades. If most of that is spent on foreign kit and imported expertise, much of the value leaks overseas. If instead the UK builds SMR modules, electrolysers, piping, valves, instrumentation, grid equipment and control systems at home, the same money supports UK factories, wages and tax receipts.

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# 7. A Hydrogen-Heavy Future: 2055 Without Fossil Fuels

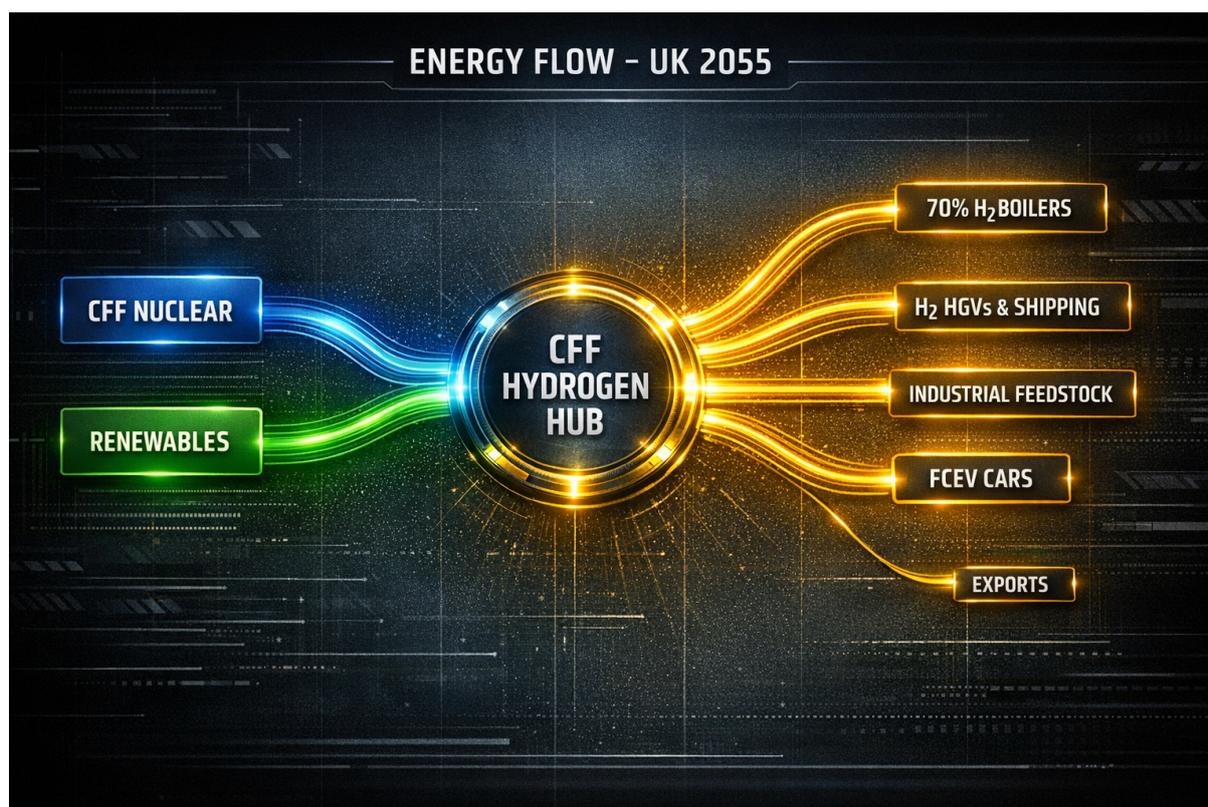
To understand how CFF fits into the bigger picture, it helps to imagine the UK energy system in 2055 if the programme has been fully built out and fossil fuels have been phased out.

## 7.1 A hydrogen-first pathway

In this future, the UK has chosen a hydrogen-heavy path rather than a pure electrification path. Roughly:

- About **70% of space and water heating** is provided by hydrogen boilers.
  - About **20% of heating** is supplied by electric heat pumps (ASHPs).
  - **70% of cars and vans** use hydrogen fuel cells; the remaining 30% are battery electric.
  - All heavy transport—HGVs, rail where not electrified, most shipping—is powered by hydrogen or hydrogen-derived fuels.
  - Most high-temperature industrial heat and many chemical feedstocks come from hydrogen, not fossil gas or coal.
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## 8. 2055 UK Energy Flow: Big Picture



*Illustrative 2055 UK energy flow with CFF as the hydrogen and flexibility backbone.*

## 9. Risks and Challenges: What Could Go Wrong?

A project of this magnitude is not without significant risks. Success depends on navigating several critical hurdles:

- **Supply Chain Bottlenecks:** Building 175 SMRs requires a massive scale-up of UK manufacturing. If the supply chain cannot keep pace, costs will spiral and timelines will slip.
- **Regulatory Approval:** The "fleet" approach relies on Generic Design Assessment (GDA). Any major design changes required by regulators mid-program would break the modular economic model.
- **Public Acceptance:** While coastal sites are remote, the sheer number of sites (25) and the associated hydrogen pipelines require a strong national consensus and local community buy-in.
- **Skills Gap:** Transitioning 100,000+ workers from oil and gas requires a flawless execution of the "Skills Passport" program. A shortage of specialized nuclear or hydrogen engineers could stall the rollout.
- **Technological Maturity:** While the components (SMRs, PEM electrolyzers) exist, integrating them at this unprecedented scale has never been done. System-level failures in the "sea-to-street" interface could impact efficiency.

- **Political Continuity:** A 25-year build-out requires cross-party support that survives multiple election cycles. A withdrawal of state backing halfway through would leave the UK with stranded assets.

## Appendix: 2055 Capacity and Energy Numbers (Illustrative)

These figures are indicative, to give a sense of scale and balance. They are not a forecast, but a worked example of how a fully built-out CFF system could sit alongside renewables in a fossil-free UK.

### Appendix A1 – Installed Capacity by Technology (2055)

Source / Technology	Capacity (GW)	Notes
CFF SMR Nuclear (25 sites, 7 SMRs each)	82	Coastal mega-sites; main hydrogen and firm power backbone
Other Nuclear (Hinkley, Sizewell, etc.)	10	Large reactors feeding directly into the grid
Offshore Wind	80	North Sea and Irish Sea; high capacity factor fleet
Onshore Wind	20	Planning-reformed onshore programme
Solar PV	50	Mostly rooftops with some utility-scale
Hydro + Tidal + Other Renewables	5	Includes some tidal stream and lagoons

### Appendix A2 – Annual Electricity Output (Before Conversion)

Source	Annual Output (TWh/year)	Comment
CFF SMR Nuclear	2,000	Majority routed to electrolyzers, remainder to grid
Other Nuclear	100	Grid-focused baseload
Offshore Wind	220	Variable, but high utilisation
Onshore Wind	40	Typical UK onshore capacity factors
Solar PV	40	UK solar resource; strong summer contribution
Hydro + Tidal + Other	10	Small but predictable contribution
Net Imports (Interconnectors)	10	Net position after exports and imports

### Appendix A3 – How CFF Power Is Used

Flow		Notes
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	<b>Electricity In (TWh/year)</b>	<b>Output (TWh/year)</b>	
CFF → Electrolysers (Hydrogen route)	1,500	1,050 H <sub>2</sub>	Assumes ~70% efficiency from electricity to hydrogen (LHV)
CFF → Grid (Direct electricity)	500	500	Firm, dispatchable power to National Grid

### Appendix A4 – Hydrogen Production and Use (From CFF Only)

<b>Hydrogen Use</b>	<b>H<sub>2</sub> Energy (TWh/year)</b>	<b>Illustrative Share</b>
Residential & Commercial Heat (Hydrogen Boilers)	250	~24%
Industrial Heat & Feedstock	220	~21%
Light Road Transport – FCEVs	80	~8%
Heavy Road Transport – HGVs	120	~11%
Rail (Non-electrified)	10	~1%
Shipping & Maritime Fuels	150	~14%
Aviation Synthetic Fuels	80	~8%
Hydrogen-to-Power (Peaking / Backup)	50	~5%
Exports / Chemicals / Fertilisers	40	~4%
System Losses (Compression, Leakage, Distribution)	50	~5%
<b>Total</b>	<b>1,050</b>	<b>100%</b>