Virtual Seminar on Climate Economics
Federal Reserve Bank of San Francisco

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Can the UK Achieve Net-zero Greenhouse Gas Emissions by 2050?

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Federal Reserve Bank of San Francisco

Virtual Seminar on Climate Economics, 13 January, 2022
(1) Climate change and its implications
(2) Historical background and summary
(3) Non-GHG ‘green’ electricity generation
(4) Decarbonize ground transport
(5) Decarbonize households and construction
(6) Decarbonize industry, chemical manufacturing and waste
(7) Reduce GHG emissions from agriculture
(8) Conclusions
Thousand-year changes of ± 25 parts per million (ppm) in atmospheric CO₂ over 800,000 years of 8 major Ice Ages coming & going.
Last 250 years of +130 ppm CO$_2$ where 1 ppm = 7800 billion kg of CO$_2$. Humans are altering the atmosphere—and hence the climate.
Increases in atmospheric CO$_2$ accelerating since 2000, increasing planet’s temperature and sea level.

Atmospheric CO$_2$ increases still increasing—despite CoP21
Increases in atmospheric CO\textsubscript{2} accelerating since 2000, increasing planet’s temperature and sea level.

Global mean surface temperature deviations

https://climate.nasa.gov/vital-signs/global-temperature/
Increases in atmospheric CO$_2$ accelerating since 2000, increasing planet’s temperature and sea level.

http://159.226.119.60/cheng/images_files/IAP_OHC_estimate_update.txt
Increases in atmospheric CO$_2$ accelerating since 2000, increasing planet’s temperature and sea level.

Rise now $0.14$ in p.a. versus $0.05$ in p.a. over 1850-1992

https://www.epa.gov/climate-indicators/climate-change-indicators-sea-level
Distributional shifts in monthly global atmospheric CO$_2$

![Graph showing distributional shifts in global CO$_2$ emissions from 1957(1) to 1972(2).](image)

- Global CO$_2$ emissions 1957(1)−1972(2)

- ppm range from 310.0 to 332.5

- Data points at 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09 ppm

- David F. Hendry (Climate Econometrics)
Distributional shifts in monthly global atmospheric CO$_2$

![Graph showing distributional shifts in global CO$_2$ emissions from 1957 to 1987.](image)

- Global CO$_2$ emissions 1957(1)−1972(2)
- Global CO$_2$ emissions 1972(3)−1987(4)

David F. Hendry (Climate Econometrics)
Distributional shifts in monthly global atmospheric CO₂

David F. Hendry (Climate Econometrics)

Can UK Achieve Net-zero Emissions by 2050?

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Anthropogenic greenhouse gas emissions from energy generation, artificial fertilizers, deforestation, animal husbandry & waste.
Implications of climate change: physical dangers

Past mass extinctions of life on Earth due to climate change: albeit ‘natural’ not anthropogenic—but now may be us by emitting excessive GHGs

Extreme weather events: more powerful cyclones and tornadoes; increased land flooding—‘rivers in the sky’ can hold more water than Mississippi River, causing great damage recently in Europe and China & lead to loss of soil; but also longer & more intense droughts & dust storms, with loss of crops; high temperatures dangerous to life from ‘heat domes’ as in North America last summer, and more generally from high ‘wet bulb’ heat; overly acidic oceans;
Implications of climate change: physical dangers

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Rivers-in-the-sky; dust-storm; wild fires; coastal flooding

[Image of a map showing weather patterns]

[Image of a dust storm]

[Image of a wildfire]

[Image of coastal flooding]

https://www.psl.noaa.gov/arportal
https://public.wmo.int/en/our-mandate/focus-areas/environment/SDS
https://earthobservatory.nasa.gov/images/81919/rim-fire-california
https://en.wikipedia.org/wiki/Coastal_flooding
Physical dangers inflict economic losses of varying magnitudes. Falling property values in worst affected areas could lead to widespread mortgage defaults (which led to the Financial Crisis).

Commercial banks have lent $trillions to key fossil fuel producers and users. Many aspects of financial systems threatened if sudden large reductions mandated in use of fossil fuels by major economies. Capital assets and the millions employed in affected industries could become ‘stranded’, reducing consumers’ expenditure, and investors claims on those assets could inflict large financial losses.
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Physical risks and transition risks also face huge uncertainty about policy responses & behavioural adjustments, as well as technological developments, increasing geo-climate volatility (Campos-Martins and Hendry, 2020).

Many central banks and financial regulators are therefore reacting now to monitor and adopt strategies to make financial systems more resilient: Bank of England stress tests of commercial banks include coping with climate change.
Little impact on global CO$_2$ emissions from pandemic lockdowns: just reducing GDP growth not a solution

(a) Global daily CO$_2$ emissions during 2019 & 2020 (Mt);
(b) percentage reductions in daily global CO$_2$ emissions during 2020: largest fall in April was 25Mt relative to 24,000Mt emissions p.a.
(1) Climate change and its implications  
(2) Historical background and summary  
(3) Non-GHG ‘green’ electricity generation  
(4) Decarbonize ground transport  
(5) Decarbonize households and construction  
(6) Decarbonize industry, chemical manufacturing and waste  
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(8) Conclusions
Industrial Revolution began in the UK in the mid-18th Century. Antecedents lay two centuries earlier in scientific, technological and medical knowledge revolutions.

UK was first country to industrialize on a large scale.

Industrial Revolution and its successors have since been adopted worldwide.
Background to increased greenhouse gas (GHG) emissions

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UK was first country to industrialize on a large scale.

Industrial Revolution and its successors have since been adopted worldwide.

Startling consequences 250 years later:

- real income levels are 7–10 fold higher per capita,
- many killer diseases have been tamed, & longevity has approximately doubled.

Evidence in https://ourworldindata.org/economic-growth shows even greater improvements in many other countries.

GHG emissions an unintended consequence of economic development.
Industrial Revolution of huge benefit to humanity

Average real GDP per capita across regions
The measures are adjusted for inflation (at 2011 prices) and also for price differences between regions (multiple benchmarks allow for cross-regional income comparisons).

Source: Maddison Project Database (2018) OurWorldInData.org
Historical developments: electricity, greenhouse gases, protecting nature

So close to all electric societies 120 years ago—and yet so far

1838 first fuel cell invented by Sir William Grove;
1839 first photovoltaic cell created by Edmond Becquerel;
1856 a flask of CO$_2$ heated greatly in the sun, dry air did not, shown by Eunice Foote;
1859 that finding confirmed in independent experimental evidence by John Tyndall;
1864 Yosemite placed under federal protection by Abraham Lincoln
1868 first UK electricity hydro generated by Sir William Armstrong;
1883 first commercial photovoltaic solar panel by Charles Fritts;
1887 first wind turbine to generate electricity by James Blyth;
1880s electric car with high-capacity rechargeable battery by Thomas Parker;
1896 atmospheric temperature change proportional to $\Delta(\log \text{CO}_2)$: Svante Arrhenius.
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But US buyers and motor manufacturers switched to internal-combustion vehicles which soon outcompeted electric cars in both total cost and distances travelled.
Back to an all-electric future where humanity might have been 120 years ago?

David F. Hendry (Climate Econometrics)
Bersey Electrical Cab, 1897

Nansen’s ship Fram in Arctic 1893–6 with windmill for electric lighting

Sensitive intervention points linked by non-GHG generated electricity

A sensitive intervention point (SIP: see Farmer et al., 2019) is when a system is near a critical (or tipping) point so a small change triggers a much larger change that then becomes essentially irreversible.

Sensitive intervention points in the post-carbon transition to leverage policy actions (e.g., legally-binding 2008 UK Climate Change Act, CCA08) and technology developments (e.g., solar PV and wind cheaper sources of energy than fossil fuels).
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**Five SIPs to reduce GHG emissions are:**

2. **Electric-powered vehicles** connected to a smart grid (V2G) for large-scale short-run backup storage to balance variable renewables generation.
3. **Low-cost hydrogen** produced from intermittent ‘surplus’ renewables electricity;
4. **Liquid hydrogen** as medium-term storage and a high-heat source for industry;
5. **New electricity-based agriculture** like plasma waves to reduce amonia pollution.
Recent published proposals for getting to net-zero emissions

- Detailed analyses in MacKay (2009);
- well-known IPCC reports such as IPCC (2021);
- Larson, Greig, and Jenkins (2020) Princeton report for the USA;
- UK Climate Change Committee [https://www.theccc.org.uk/publication/sixth-carbon-budget/](https://www.theccc.org.uk/publication/sixth-carbon-budget/)
- UK Government’s (2021) *Net zero strategy: Build back greener*
- IEA (2021) *Net zero by 2050*
- Fries (2021) *Transforming Energy Systems*
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Agreement that technically can decarbonize electricity generation by **2050**;
less agreement on doing so reliably at scale, decarbonizing ground transport & V2G, and on roles for bioenergy with carbon capture and storage (BECCS).

Differences in tackling storage for variable renewable electricity;
in decarbonising housing, construction, industry and agriculture.

Latest UK report proposes many of the steps in our *Evidence to Forty-Sixth Report of Session 2019–21, UK House of Commons Public Accounts Committee [https://committees.parliament.uk/writtenevidence/21638/html/](https://committees.parliament.uk/writtenevidence/21638/html/), but important gaps.*
Where is the UK now in controlling its GHG emissions?

UK territorial per capita CO\textsubscript{2} emissions (tons p.a.) till 2020

In 2013, fell below 1860 levels when UK was ‘workshop of the world’.
UK real GDP per capita rose by 58% between 1997 and 2019, approximately 2% p.a., despite ‘great recession’.
Coal (millions of tonnes, Mt), oil (Mt), natural gas (millions of tonnes of oil equivalent, Mtoe) and wind+solar (Mtoe), all to 2019.
Main non-coal sources of UK domestically generated electricity

- Nuclear
- Renewables
- CCGT

CCGT: Combined Cycle Natural Gas Turbine.

More than 20TWh of electricity imported via interconnectors in 2019
CO$_2$ emissions strongly affected by existing capital stock: Pfeiffer et al. (2016).

Ratio of CO$_2$ emissions to capital stock, 1860–2015, fell by 92%.

‘Stranded assets’ problematic if legislation lowers CO$_2$ targets and financial markets not adjusted.
Massive changes in relationships over time

Plot of CO$_2$ emissions against the quantity of coal by date.
Distributional shifts of total UK CO2 emissions in Mt p.a.

UK CO2 emissions, 1860−1899

David F. Hendry (Climate Econometrics)
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- UK CO2 emissions, 1860−1899
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UK CO\textsubscript{2} emissions, 1860−1899
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- UK CO2 emissions, 1980−2019

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Non-GHG ‘green’ electricity generation

Could eliminate coal, oil & natural gas from electricity generation: needs **massive increase, linked grids & storage** to balance supply facing greater variability in renewables (V2G), & for still, cloudy periods (hydro pump & store, batteries, supercapacitors, liquid hydrogen, flywheels, etc.).

**As oil produces 30% more CO$_2$ per kwh than methane**, expand non-GHG electricity for electric vehicles before replacing natural gas in electricity generation.
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**As oil produces 30% more CO\textsubscript{2} per kwh than methane**, expand non-GHG electricity for electric vehicles before replacing natural gas in electricity generation.

Back up renewable electricity generation by safe small modular nuclear reactors (SMRs) based on well-developed nuclear engines in submarines, as well as large ‘conventional’ nuclear reactors.

Castle and Hendry (2020) econometric model shows **UK climate policy has been effective**: big reductions in territorial CO\textsubscript{2} emissions at little aggregate cost as renewable-electricity now fully competitive.
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Technical issues to research: storage systems; economies of scale making SMRs, & their use of transuranic waste & thorium; potential from fusion.
Non-GHG energy

Wind turbines & solar photovoltaics fallen in cost and increased in efficiency so rapidly over last two decades that, for the UK, they offer lowest cost alternatives if carbon capture and storage (CCS) is enforced.

Easier to install & dismantle offshore wind turbines given 100 meter-long blades. Hywind Scotland trial of floating wind turbines has demonstrated their viability. However, evidence that wind speeds falling due to reduced temperature differentials between tropics and poles.

Energy generated using waves near Orkney and tides off Shetland: tidal movements of twice daily ebb and flow predictable, so is energy from underwater turbines.

Nuclear power is successful safe low-cost electricity producer in France, about 70%. Nuclear accidents have cast a pall over that technology, but has one of lowest death rates of energy sources. As most nuclear power plants are coastal and off-shore wind turbines little affected by 'tsunamis' & resilient to earthquakes, could maintain power for cooling & help avoid accidents like Fukushima Daiichi.
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### Expected levelised costs for power generation technologies in £/MWh

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Lowest cost for each year in **bold**.

MWh = megawatt hour

Source 2015–2040: Table 4.18 central case, Electricity Generation Costs 2020, UK Department for Business, Energy and Industrial Strategy (BEIS). BEIS rankings assume increasing carbon taxes and falling CCS costs over time. Source 2050: Table 7.2 in on Climate Change (2019). Levelised (life-cycle) cost is the discounted lifetime cost of building and operating in £/MWh: the different expected costs are determined by various differences in assumptions. The price of £92.50/MWh from 2023 for nuclear power was guaranteed for the output from Hinkley Point C.
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Will just ‘green’ electricity be possible?

UK total energy use in 2018 was \( \approx 2250 \) terawatt hours (TWh): 70Mtoe petroleum, 70Mtoe natural gas & 60Mtoe non-GHG. Electricity production was 350TWh, 120TWh from renewables, so a **20-fold** expansion in renewables just to replace GHG emitters.

Need staged approach integrated across all sectors: will take several decades given scale of transition, requiring major infrastructure expansions to install and ensure continuous electricity provision (compound annual growth rate \( >10\% \)), extensive skills training for building, servicing and maintaining a green economy, and some substantial technological advances, albeit not science-fiction: 3 decades looks fast.
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Time horizon of 2050 may be too late to keep global temperatures below $2^\circ C$, but lowers costs of switching to non-GHG alternatives: most vehicles, domestic appliances and industrial equipment need replacing anyway over 30 years, so net costs may be negative if rapid technical progress & volume cost reductions.

But if large increases in extreme weather events, public may demand far faster adjustment leading to disorderly energy markets and potential financial instability.
Testing the UK’s achievement of its 2008 Climate Change Act targets

(a) CO₂ Emissions
- UK CC Act 2008 CO₂ Target
- CO₂ Emissions

(b) CO₂ Target Difference
- Selected step indicators

\[ \hat{T}_{\text{TargDiff}} = 52.3^{(9.1)} + 49.9^{(17)} - 101^{(16)} \] 
\[ \hat{\sigma} = 15.7 \] 
\[ R^2 = 0.85 \] 
\[ F = 0.38 \] 
\[ \chi^2 nd = 0.48 \] 
\[ F_{\text{arch}} = 0.02 \] 
\[ F_{\text{Reset}} = 0.00 \] 

Emissions \( \approx 52 \) Mt below target after 2013 & 50 Mt more after 2019, part from lockdowns.

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Can UK Achieve Net-zero Emissions by 2050?
Testing the UK's achievement of its 2008 Climate Change Act targets

\[ \text{TargDiff}_t = \hat{52.3} \quad S_{2013} + 49.9 \quad S_{2019} - 101 \quad (9.1) \quad (17) \quad (16) \]

\[ \hat{\sigma} = 15.7 \quad R^2 = 0.85 \quad F_{\text{arch}}(1, 9) = 0.38 \quad \chi^2_{\text{nd}}(2) = 0.48 \]

\[ F_{\text{arch}}(1, 11) = 0.02 \quad F_{\text{Reset}}(2, 8) = 0.00 \quad T = 2008 - 2020 \]

Emissions \approx 52\text{Mt} \text{ below target after 2013} \& 50\text{Mt} \text{ more after 2019}, \text{ part from lockdowns.}
Simulating CCA08’s aim of 80% reduction by 2050 from 1990 base of 590 Mt.

**CO₂ emissions must drop by 120 Mt pa.**

Simulated a scenario with no coal and 70% fall in oil use to around 20 Mt p.a.

Must reduce natural gas to 35 Mtoe p.a. (75% reduction) & at least halve CO₂ emissions from agriculture, construction and waste (currently c 100 Mt p.a.).
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(c) Scenario reductions required in coal and oil use; (d) resulting reductions in CO₂ emissions from the model, compressed to 5-year intervals after 2015.

Need to add other GHG & CO₂ embedded in net imports for full appraisal.
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Decarbonize ground transport cutting both CO\textsubscript{2} and nitrous oxide

Harder, but possible by steady natural replacement of internal-combustion cars (UK average life \textlt;9 years) with electric: UK sales of new gasoline and diesel cars will end by law in 2030; fuel cells & hydrogen drive-trains for large trucks & UK railways. To sustain \textbf{100\%} electric, research modular graphene-based \textbf{carbon nanotube} units (CNTs) as electrode supercapacitors for storing electricity & in vehicles for recharging batteries. Solid-state and blade batteries rapidly improving.
Decarbonize ground transport cutting both CO$_2$ and nitrous oxide

Harder, but possible by steady natural replacement of internal-combustion cars (UK average life <9 years) with electric: UK sales of new gasoline and diesel cars will end by law in 2030; fuel cells & hydrogen drive-trains for large trucks & UK railways.

To sustain 100% electric, research modular graphene-based carbon nanotube units (CNTs) as electrode supercapacitors for storing electricity & in vehicles for recharging batteries. Solid-state and blade batteries rapidly improving.

Vehicle-to-grid (V2G) could provide low-cost-investment short-term electric storage system. Vehicles plugged into intelligent grid when parked paid peak prices if discharged.

If viable, CNTs offer sufficiently light electric power to advance developments in electric aircraft.

Technical issues to research: supercapacitors and batteries; intelligent standardised infrastructure for charging-discharging points and two-way payments.
Log scales, matched in 1949. 10-fold increase in distances driven despite more than doubling in real petrol prices: not very effective carbon tax–but has tilted balance to EVs being lifetime cheaper.
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(7) Reduce GHG emissions from agriculture
(8) Conclusions
Decarbonize households and construction

Retrofit old buildings by improved insulation

Then heat pumps are effective. Triple glazing from ‘surplus’ electricity. Replace some household natural gas by hydrogen once all electricity non-GHG. Produce by methane pyrolysis + electrolysis when ‘surplus’ electricity: also store as liquid hydrogen. Pyrolysis by-product of black carbon for graphene.
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#### New buildings need zero GHG materials like glulam

Laminated wood to replace some steel. Concrete 30% stronger if add graphene, & magnesium oxide for carbon-eating cement. Install heat pumps, solar photovoltaics & evacuated-tube solar collectors on roofs or switch to hydrogen boilers.

Needs major improvements in infrastructure to pipe hydrogen, preceded by better CCS in its manufacture, and better designed, greener, cities.
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Technical issues to research: perovskite-based solar windows to generate electricity; lower GHG refrigerants & non-GHG building materials.
UK has just over 3 million hectares of woodland at roughly 1000 trees per ha. Aim is for 30,000 ha p.a. additional planting. But vast majority of UK timber imported.
(1) Climate change and its implications
(2) Historical background and summary
(3) Non-GHG ‘green’ electricity generation
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Liquid hydrogen as high heat source for industry

Also electric arc methods. Both require non-GHG electricity generation: self-defeating to use natural gas based electricity to make hydrogen.

CCS and CO$_2$ extraction will remain essential as chemical manufacturing uses some coal, oil and natural gas.
Decarbonize industry, chemical manufacturing and waste

Liquid hydrogen as high heat source for industry

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New four Rs are repair, reuse, recycle, reduce: 5 pence charge per plastic bag in 2015 led to 13 billion fewer bags (an 80% fall) after 2 years. Try similar charges for other non-recyclable items like disposable coffee cups.

Technical issues to research: Efficient liquid hydrogen production; reformable plastics; CCS methods; CO$_2$ absorbers; CO$_2$ extraction with efficient separation & collection of useful gasses, & convert CO$_2$ to a useful fuel

https://doi.org/10.1016/j.xcrp.2020.100210

Fund research by prizes—successful historical route: Hendry (2011).
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Essential to reduce GHG emissions from agriculture: get down to *Earth* for a lower ‘foodprint’ with less food waste!

**Reduce CO$_2$ emissions: stop deforestation, peat use; restore wetlands & mangroves**

Plant appropriate trees and vegetation to re-absorb CO$_2$.

**Reduce nitrous oxide emissions by less artificial fertiliser: basalt + biochar**

Land round volcanoes very fertile so use basalt dust (+$\text{ absorbs CO}_2$); cut cropland & environmental damage by more efficient crop production, zero-till, biochar, bury slurry; vertical & underground farms cost effective with LED lighting.
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**Improve aquaculture production by marine protection areas**

Seaweed farming (kelp, seagrass, asparagopsis) also cuts NoX pollution; off-shore wind farms can act as marine reserves.

**Technical issues to research:** breed low methane ruminants; high protein meat substitutes; biochar production; seaweed farming; changes to human diets.

David F. Hendry (*Climate Econometrics*)
Sheep on the island of North Ronaldsay in the Orkneys

Reduce methane from ruminants by dietary changes, selective breeding

Fumaric acid; *asparagopsis taxiformis*, seaweed as on North Ronaldsay
Sheep on the island of North Ronaldsay in the Orkneys

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Fumaric acid; *asparagopsis taxiformis*, seaweed as on North Ronaldsay

Ancient breed of local sheep forced to live off seaweed on the beach by a dry stone dyke round the island: controls methanogenic bacterial activity, so they belch far less methane than grass-fed ones. High grass diet dangerous from copper intake.
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Summary for UK achieving net-zero GHG emissions by 2050.
What can be done?

Five key sensitive intervention points (SIPs) given green electricity

1] First **vastly expand non-GHG electricity** so no coal → much less CO$_2$
2] **Decarbonize ground transport** so no oil, plus electricity storage in V2G
3] **Decarbonize households & construction** so no natural gas
4] **Decarbonize industry** so less of all fossil fuels
5] **Reduce agriculture GHG ‘foodprint’** so less CO$_2$, nitrous oxide & methane

UK’s total CO$_2$ higher as some embodied in net imports. To reduce, impose import tariffs on countries not reducing their GHG emissions (Nordhaus, 2020) or deforesting, threatening species extinctions (https://www.nicfi.no/).

Cap and trade like the EU Emissions Trading System could help facilitate GHG reductions where coal still widely used.

Also increase taxes on oil and gas as prices fall to maintain shift to all electric.
Conclusions on reducing CO$_2$ emissions

Having been first into the Industrial Revolution that has transformed the world’s wealth at the cost of climate change, the United Kingdom is one of the first out in terms of its CO$_2$ emissions.

Per capita UK CO$_2$ emissions now below their level in 1860—when the UK was the ‘workshop of the world’—yet per capita real incomes are more than 7-fold higher.

UK climate policy has been effective so far: large reductions in CO$_2$ emissions have had only a small aggregate cost, but local losses were not addressed and must be in future for a ‘just transition’. ‘Stranded people’ must not be abandoned.
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The UK’s reductions of 240 Mt since 1990 (40%) are the more impressive against global increases of about 23,000 Mt annually. But much more difficult to get near net-zero GHG emissions—which is necessary, not sufficient.

At a global level, total accumulation of atmospheric GHGs determines temperature increases and climate change, so the trajectory of getting to net-zero matters greatly—the faster emissions are reduced the less damaging.
Policy implications: creating virtuous circles using SIPs

Integrated GHG reduction strategy and its timing essential for net-zero target. Replacing oil by non-GHG electricity entails huge expansion: hence vast storage requirement to balance instant and long-term supply and demand (so V2G & liquid hydrogen from ‘surplus’ electricity). Further large non-GHG increase needed to remove natural gas from electricity generation, then make hydrogen when ‘surplus’, and replace household use. Liquid hydrogen then also available for industrial use. Green electricity facilitates basalt grinding, plasma waves, etc. in agriculture, as well as vertical and underground farms.

David F. Hendry  
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Achieving net zero can be done at relatively low cost, but unclear the UK will do it.

Thank you

https://www.climateeconometrics.org/
https://www.climateeconometrics.org/publications-working-papers/#discuss
References I


## Relative emissions of fuel sources

<table>
<thead>
<tr>
<th>Fuel Source</th>
<th>CO₂ Emissions (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal (anthracite)</td>
<td>228.6</td>
</tr>
<tr>
<td>Coal (bituminous)</td>
<td>205.7</td>
</tr>
<tr>
<td>Coal (lignite)</td>
<td>215.4</td>
</tr>
<tr>
<td>Coal (sub-bituminous)</td>
<td>214.3</td>
</tr>
<tr>
<td>Diesel fuel &amp; heating oil</td>
<td>161.3</td>
</tr>
<tr>
<td>Gasoline</td>
<td>157.2</td>
</tr>
<tr>
<td>Propane</td>
<td>139.0</td>
</tr>
<tr>
<td>Natural gas</td>
<td>117.0</td>
</tr>
</tbody>
</table>

Pounds of CO₂ emitted per **293 kWh** of energy produced.