Infrastructure Requirements for Zero Carbon

Why we can't build our way out of the climate emergency

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GREEN HOUSE THINK TANK

GEF GREEN EUROPEAN FOUNDATION

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Preface

'It should not be news that humanity must exist within climate and environmental limits, or that currently we aren't doing so.' This is the first line of 'Trade and Investment Requirements for Zero Carbon', published in August 2020 as part of Green European Foundation's Climate Emergency Economy Project. This follow-up report considers the infrastructure – the physical structures and facilities (e.g. roads and electricity generation) – required for a zero carbon economy. It explores how compatible our society's current and planned infrastructure is with zero carbon before considering what changes would be required for the necessary transition. The latter part is done through the lens of 6 of the 20 'blockers' and 'enablers' introduced in the policy toolkit proposed in the previous report. [1]

It is clear there is a huge amount of work to be done to adapt existing buildings and transport infrastructure; however, the biggest challenge is around the infrastructure already planned for between now and 2050. The UK already has a zero carbon emissions target for 2050, and it is clear that for the UK to make equitable contribution to limiting global temperature rise to 1.5°C, zero carbon must be reached much sooner.[1,2] Much of our existing industrial infrastructure (e.g. fossil fuel power stations and steel blast furnaces) is incompatible with zero carbon, whilst planned new infrastructure threatens to take our economy in the wrong direction by increasing the scale and geographic disconnect of resource extraction and use.[3]

Our previous report highlighted the need for trade to be smaller (in tonnage), with shorter supply chains and slower transport. Current investment in airports, shipping and international trade routes is taking us in the opposite direction. We need a shift away from infrastructure investments that encourage us collectively to build more, buy more and travel more, and a shift towards an economy where investment drives a change to smaller, circular economies that fit within environmental limits.[4] This will allow us to manage our demand for energy and materials down to levels compatible with zero carbon.

This report focuses on the freight transportation, aviation and steel sectors, which, combined with cement and plastic production, currently account for around 10 gigatonnes (Gt) of carbon dioxide (10 $GtCO_2$ = 10 billion tonnes) annually.[5] To ensure **Sufficient Action** is being taken, our society must target the rates of change required for a rapid transition to zero carbon. The speed and carbon budget(s) for this transition must take a precautionary approach and be globally equitable.

For sufficient action to be achieved, **Government Sets Direction** is critical to ensure our economies stop **Choosing the Wrong Scale**. Governments at all levels, must **Manage Demand** to ensure the infrastructure transition is viable and avoid dangerous **False Horizons**. In parallel, ensuring **Public Money for Public Goods** is critical both to ensure that our society stops **Locking in Harm** and to create the infrastructure required for zero carbon. This along with **Taxing Harm** will allow our economy to **Investing in What We Already Have** so that sufficient infrastructure can be delivered.

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1 UK Government (2008) 'Climate Change Act 2008'.

2 Jackson, T (2019) 'Zero Carbon Sooner', CUSP Working Paper 18, *CUSP*.

3 Hildyard, N, and Sol, X (2017) 'How Infrastructure is Shaping the World: A Critical Introduction to Infrastructure Mega-Corridors', *The Corner House*.

4 Essex, J (2014) 'How to Make Do and Mend our Economy: Rethinking Investment Strategies for Construction and Industry to meet the Challenge of Sustainability', *Green House Think Tank*; Blewitt, J (2014) *The Post-Growth Project: How the End of Economic Growth Could Bring a Fairer and Happier Society* (London: London Publishing Partnership).

5 Energy Transitions Commission (2018) 'Mission Possible: Reaching Net-Zero Carbon Emissions from Harder-to-Abate Sectors by Mid-Century', Executive Summary.

The Unsustainable Infrastructure Status Quo

Plans for new global infrastructure are completely unsustainable. The world is expected to invest around $90 trillion in new infrastructure over the next 15 years, which would more than double the amount of infrastructure that already exists.[1]

One example is the myriad schemes across 120 countries that comprise China's Belt and Road Initiative (BRI). By 2018 one of these new transport corridors already supported some thirty trains a week running from Chongqing in China to Duisport in Germany, the world's largest inland port. Whilst switching trade from shipping and planes to rail may have climate benefits,[2] this fails to account for the vast embodied carbon invested in constructing and maintaining this infrastructure, let alone the additional trade it stimulates.

Around the world, ports are being deepened, 'airport cities' built and transport networks expanded. Schemes include the Trans-European Transport Network (TEN-T) and the Programme for Infrastructure Development in Africa.[3] Expanding transport infrastructure raises transport demand, increasing both the vast distances and speed that goods travel, wrapping supply chains around the world.

Why? Cheap transport, reflecting the absence of fuel taxes or carbon targets on global freight, means that factories no longer need to be sited near raw materials or consumers but can be built wherever labour is cheap, taxes low and regulatory regimes favourable. This has led to a proliferation of special economic zones, now also proposed in the UK.[4] Global trade patterns are governed by the comparative advantage that different countries have in producing different products.[5] Alongside

1 New Climate Economy (2016) The Sustainable Infrastructure Imperative: Financing for Better Growth and Development.
2 Dunmore, D, et al. (2019) 'The "Belt and Road Initiative": impacts on TEN-T and on the European transport system'. *Journal of Shipping and Trade* 4:1, p.10.
3 AfDB (2016) 'Programme for Infrastructure Development in Africa (PIDA): Interconnecting, integrating and transforming a continent'.
4 The UK government consulted on establishing freeports (tax-free or low-tax zones) across the UK in 2020. See www.gov.uk/government/consultations/freeports-consultation.
5 UNCTAD (2020) 'Revealed Comparative Advantage'.

transport infrastructure, giant logistics and distribution centres are being extended, integrated and automated at a greater scale, serving as centralised hubs to distribute goods across whole countries.

Logistics – the management of the flow of goods between the point of origin and the point of consumption – is now the world's largest industry, driving outsourcing and offshoring worldwide, and creating globalised supply chains that 'lock in' air and sea freight.[6] Together these global trends are maximising the extraction not just of environmental but human 'resources': increasing corporate power at the expense of workers' rights and the environment. These global supply chains are being managed a small number of huge companies – for example, just ten global shipping lines now run nine-tenths of container shipping.[7]

Transport Infrastructure and Carbon Emissions

The UK reflects these global trends. Doubling infrastructure investment, including airport expansion, sits at the heart of the UK's economic strategy.[8],[9] Over half of the UK government's planned spending on infrastructure and construction will be on transport[10] – including £72–£98 billion on the new high-speed railway HS2[11] and £27 billion on England's main road network over the next five years,[12] equivalent to funding a further 4,500 lane-miles of motorways, based on current prices.[13]The expansion of transport infrastructure is reflected in greenhouse gas emissions trends. Transport emissions are still going up whilst the carbon footprint of heating buildings and producing electricity have slowly reduced. Since 1990 transport's share of the UK's carbon footprint has almost doubled to 37%, once international aviation and shipping are included (see **Table 1**).

	Emissions ($MtCO_2e$)		
Type	**1990**	**2018**	**Change since 1990 (%)**
Cars	72.3	68.5	-5.3%
Road freight	**32.1**	**40.2**	**25.1%**
Buses and Trains	7.2	5.0	-31.3%
Shipping (1)	16.6	13.8	-16.9%
Aviation (1)	**17.0**	**38.2**	**124%**
Military	5.6	2.2	-60.3%
Total (2)	151.8	168.9	11.3%
% of total UK emissions (3)	19.1%	37.4%	95.7%

Table 1: Breakdown of UK Transport Emissions 1990–2018

Source: BEIS (2020) 'Final UK greenhouse gas emissions national statistics: 1990 to 2018', Data Tables, Tables 3 and 8.

Notes: 1. Includes both domestic and international shipping and aviation.
2. Also includes motorbikes and road vehicle LPG and biofuels (1 $MtCO_2e$).
3. Compared to the total territorial greenhouse gas emissions for the UK.

6 See Hildyard, N (2018) Corridors as Factories: Supply Chains, Logistics and Labour - Is This the World You Want? Published by The Corner House, UK.

7 UNCTAD (2019) 'Review of Maritime Transport 2019'.

8 UK Government (2017) 'Industrial Strategy: Building a Britain fit for the future'.

9 HM Treasury (2020) National Infrastructure Strategy

10 UK Government (2020) 'Analysis of the National Infrastructure and Construction Procurement Pipeline 2020/21', Table 1.

11 Department for Transport, HS2 Ltd (2020) 'HS2 6 monthly report to Parliament'.

12 Department for Transport (2020) 'Road Investment Strategy 2: 2020–2025'. Separate budgets apply to Scotland, Wales and N. Ireland.

13 See UK Parliament (2016) 'All lane running: costs'. Average of 2020 costs for schemes in Table 4.

The 11% rise in the UK's transport carbon emissions has been largely down to freight emissions rising 25% and aviation skyrocketing by 124%. Yet both the Paris Climate Agreement and the UK's Climate Change Act only require greenhouse gas emissions produced within the UK's territorial boundaries to be measured and reduced, explicitly excluding international shipping and air transport. This creates a disincentive to invest in hard-to-decarbonise sectors, much of which has been progressively offshored.

Efficiency is not the problem. For most forms of transport, increases in fuel efficiency have outstripped increased vehicle miles, and UK road and rail freight is already the ninth most efficient freight system worldwide.[14] The key issue is the continued growth in domestic road freight and international aviation, supported by infrastructure. Domestic and international freight now make up an eighth of UK territorial emissions.[15]

What does Sufficient Infrastructure Look Like?

The climate emergency demands a different approach going forward that reflects climate science and fair global climate budgets. Whilst at the time of writing the UK is one of only six countries to have a legally binding target to cut its greenhouse gas emissions,[16] the 2050 net zero deadline is not soon enough. In order to take its fair share of a global carbon budget, the UK must reach net zero by 2030 or earlier.[17,18]

The 'avoid, shift, improve' framework developed for decarbonising transport could be applied to infrastructure systems generally.[19] To bring about a zero carbon economy we must:

- **avoid** expanding infrastructure and the built environment it supports
- **shift** to a more regional and sustainable scale
- **improve** infrastructure – so industry and our whole society are completely powered by renewable energy and do not deplete or further degrade ecosystems.

The size and nature of our infrastructure and buildings determine the amount of energy and resources used to make and transport everything we build and buy – from construction materials and cars, to computer and coffee cups. Thus to scale down production and consumption emissions, we must also scale down and decarbonise infrastructure systems.

The following sections explore how this avoid-shift-improve framework will change how we generate and store energy; transform industrial production, focusing on steelmaking; and rethink transport systems and supply chains.

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14 National Infrastructure Commission (2019) 'Better Delivery: The Challenge for Freight'.

15 UK freight road and rail freight accounted for 6% of UK emissions in 2018 (Ibid.). International aviation and shipping were estimated to be at least 23.1 $MtCO_2e$ for imports and 15.2 $MtCO_2e$ for exports in 2019. See Sims, P, and Essex, J (2020) 'Trade and Investment Requirements for Zero Carbon'. Table 1.

16 By 2020 five countries had legislated a net zero greenhouse gas emissions target, whilst over 100 have targets proposed or under discussion. See Energy Transitions Commission (2020) 'Making Mission Possible: Delivering a Net-Zero Economy (Version 1.0)'.

17 UK Government (2019) 'The Climate Change Act 2008 (2050 Target Amendment) Order 2019' (accessed July 2020).

18 Jackson, T (2019) 'Zero Carbon Sooner', CUSP Working Paper 18, *CUSP*.

19 See Joseph, S, et al. (2020) 'State of the Nations: Transport Planning for a Sustainable Future', *Transport Planning Society*.

Energy: Time to Start Reducing Demand

Strategies for full decarbonisation of the UK economy, as highlighted by the Centre for Alternative Technology, require us to rapidly 'power-down' our overall energy demand as we 'power-up' our renewables generation and storage capacity to the same level.[20] Reaching zero emissions even by 2050 would require energy use to shrink to 60% of current levels.[21]

The National Grid's first modelling of a zero carbon transition for the UK concluded that a focus on decentralised renewable energy generation would be the fastest way to decarbonise the UK.[22] This will approach will also minimise the cost of transitioning to zero carbon. Research has shown that improving energy efficiency, material efficiency and service efficiency will cost 40% less than the supply-side-only decarbonisation.[23]Yet both energy supply and demand in the UK is still rising, which is reflected in a growing 'carbon gap' between the UK's five-year carbon budgets and predicted future greenhouse gas emissions.[24] Unless fossil fuel extraction and burning is rapidly phased out, adding renewable production will increase overall energy supply, encouraging demand for energy to increase. The current focus on divesting from fossil fuel extraction needs to extend to stopping both new fossil fuel extraction and new infrastructure associated with fossil fuel use, including in the UK. But fundamentally this is still **Asking the Wrong Questions** – instead of just halting infrastructure growth we need to question how much smaller our infrastructure should become.

Taking sufficient action on infrastructure from an energy perspective requires:

- Rapidly phasing out not just fossil fuel extraction, production and burning
- Managing demand by considering the scale and nature of non-energy infrastructure that feeds energy consumption, including that related to international travel and trade
- Accounting for the embodied emissions of infrastructure in planning how we will stay within future national carbon budgets
- Not relying on offsetting emissions nor paying other countries to decarbonise first
- Relying on proven technologies that can be delivered locally rather than technologies not yet proven at scale.

A Sufficient Steel Economy

Transitioning to green steelmaking is vital to the UK industry's long-term future and could save around 15 million tonnes of CO_2e/year:

- Shifting the UK's remaining 5.7 million tonnes of blast furnace steel production to electric arc furnaces powered by 100% renewable energy would cut the emissions

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20 Allen, P, et al (2019) 'Zero Carbon Britain: Rising to the Climate Emergency', *Centre for Alternative Technology* (CAT).

21 Allwood, J, et al. (2019), 'Absolute Zero: Delivering the UK's Climate Change Commitment with Incremental Changes to Today's Technologies', *UK FIRES*.

22 National Grid (2019) 'Future Energy Scenarios', Section 6.

23 Energy Transitions Commission (2020) 'Making Mission Possible: Delivering a Net-Zero Economy (Version 1.0)'. Reducing overall global energy demand: Exhibit 1.19. Reducing costs by 37–43%: Exhibit 2.4.

24 The UK government now predicts it will exceed the cap set for the UK's fourth carbon budget (2023 to 2027) by 188 $MtCO_2$e (increased from 139 $MtCO_2$e predicted in 2019). For the fifth carbon budget (2028 to 2032) the UK's emissions are currently projected to exceed the cap set by the budget by 253 $MtCO_2$e (increased from 245 $MtCO_2$e predicted in 2019). See BEIS (2020) 'Updated Energy and Emission Projections 2019'.

of new steel from around 2.3 tonnes CO_2e/tonne to less than 100 gCO_2e/tonne,[25] saving: 12.5 million tonnes CO_2e/year.
- Replacing imported iron ore and coking coal with scrap,[26] and halving the scale of the remaining imports and exports, would save 2.5 million tonnes CO_2e/year. It would also facilitate the making of higher quality steels.

Such proposals are already being made for the blast furnaces in Port Talbot, Wales. This would require a Green New Deal to provide new employment for the two-thirds of steel workers likely to lose their jobs.[27,28] Locating some of the new electric arc furnaces across the UK would mean they could source scrap and provide steel regionally, cutting transport impacts. This should be part of an economy-wide plan to bring about a 'just transition' from such high-carbon jobs to the new green jobs across the UK.[29] The UK must also reduce existing demand to make way for the estimated 64 million tonnes of steel required for renewable energy infrastructure (see **Table 2**).[30] This is far bigger than the 4 million tonnes estimated for building HS2 and the government's current pipeline of wind and nuclear projects.[31,32,33] This steel demand combined with a shift to recycling scrap steel is visualised in **Figure 1**.

	Extra Capacity	Steel Demand	
	GW	Tonnes/MW	Million Tonnes
Solar PV (ground mounted)	55	56	3.1
Onshore Wind	39	117	4.6
Offshore Wind	140	402	56.3
Total	**234**		**64**

Sources: Calculated based on Figure 6 of Renner, M, et al. (2019) 'Measuring the socio-economic footprint of the energy transition: the role of supply chains', IRENA; and Chapman, A, et al. (2018) 'Unlocking the Job Potential of Zero Carbon', Green European Foundation, Table 9.

Table 2: Steel Requirements for new UK Renewable Energy Generation

25 Current average of 2.3 tonnes CO_2e/tonne in Figure 7 of WSP et al. (2015) 'Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050: Iron and Steel'. Allwood, J, et al. (2019, 'Steel Arising: Opportunities for the UK in a Transforming Global Steel Industry', *University of Cambridge*), highlight this could fall to 200 $kgCO_2e$/tonne (p.9). This is before considering any additional energy to manufacture the liquid steel into different products.

26 The UK currently exports more scrap steel to Turkey (alone) than is melted down into new steel in the UK. See Sims, P, and Essex, J (2020) 'Trade and Investment Requirements for Zero Carbon'.

27 BBC (2020) 'Tata Steel: Job fears at Port Talbot over furnace plan', and BBC (2020) 'Port Talbot steelworks: 'Resist Speculation' over future'.

28 Allwood, J, et al. (2019, 'Steel Arising: Opportunities for the UK in a Transforming Global Steel Industry', *University of Cambridge*, p.12) note that electric arc steel production uses around one third of the labour force as making steel from iron ore. See also TUC (2019) 'A just transition to a greener, fairer economy'.

29 Chapman, A, et al. (2018) 'Unlocking the Job Potential of Zero Carbon', *Green European Foundation*.

30 If made in a blast furnace this would result in 193 million tonnes of carbon emissions, around a quarter of the annual total for the UK – based on the global carbon intensity for making steel pipe (3.02 $kgCO_2e$/kg) in Jones, C (2020) 'Inventory of Carbon and Energy, v3.0' (accessed Nov 2020).

31 BEIS (2020, 'Steel procurement pipeline 2020') estimate that between 211 and 328 tonnes of steel are needed for each MW of installed offshore wind, based on 3 GW of offshore wind: Doggerbank (1,200 MW), Seagreen (454 MW) and Sofia (1,400 MW).

32 Unless HS2 specifically sources its steel from electric arc it will most likely be produced in blast furnaces from iron ore and coking coal, which is at odds with the project's much-vaunted climate benefits.

33 Currently 97% of Network Rail's demand for steel comes from UK steel production. See Market Line (2019) 'British Steel rescue deal vital for keeping Network Rail on track', railway-technology.com (accessed Oct 2020).

Key ways of reducing demand for steel include designing for purpose and extending the life of buildings, together with increased reclamation and reuse,[34, 35] design for deconstruction and substitution with natural materials. Combining a shift to public transport, greater car sharing and smaller vehicles could reduce steel needed for mobility by 70%.[36]

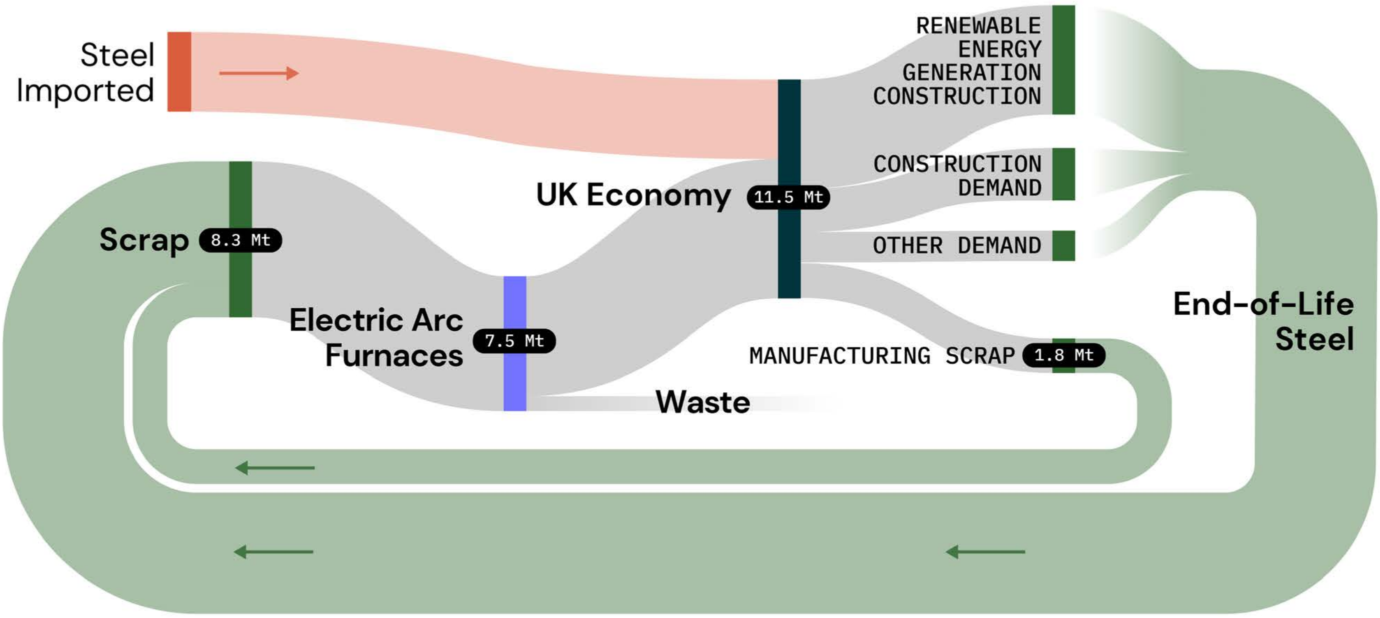

Figure 1: Proposed material flows in a sufficient UK steel economy

Note: Assuming 60% reduction in existing demand plus additional steel demand for renewable energy infrastructure outlined in Table 2 with 10% learning efficiency apply. Assuming same ratio of manufacturing scrap as 2019, a 40% reduction in demolition scrap (which is assumed to be the same ratio of total scrap as construction is of total steel demand), and no change in volumes of other scrap. Assuming 10.7% wastage from scrap to steel.[37]

Rethinking Transport

A sufficient response to the climate emergency requires a moratorium on the expansion of ports, airports, roads and logistics infrastructure along with a shift in investment strategies to enable more local and sub-national production. We need to shorten freight movements, and reduce commuting distances.

Despite the shift to electric vehicles, the emissions to make vehicles will remain largely unchanged unless trends in car ownership, vehicle occupancy and average vehicle weight are reversed.[38] This means scaling down and constraining the use of existing road infrastructure to limit the speed of vehicles and the extent to which they are used. This would reduce not only the scale of vehicle production, but also the renewable energy required, road space needed,[39] and infrastructure maintenance burden.

34 Dunkerley Steels, J (2018) 'Second-hand steel overcomes supply problems' (accessed Oct 2020).
35 Bioregional (2011) 'Reuse and Recycling on the London 2012 Olympic Park', Case Study 2.
36 Material Economics (2018) 'The Circular Economy: A Powerful Force for Climate Mitigation', Exhibit 5.7.
37 Diaconu, B, et al. (2020) 'Analysis of Energy Balance for a Steel Electric Arc Furnace', *WSEAS Transactions on Environment and Development*, 16. DOI: 10.37394/232015.2020.16.6.
38 A universal shift from car ownership to car sharing is estimated by Material Economics to reduce the material intensity of cars by 88% – crucial for electric vehicles, whose carbon is concentrated in manufacture rather than vehicle use: Material Economics (2018) 'The Circular Economy: A Powerful Force for Climate Mitigation'.
39 See the different lane capacity (persons/hour) for cars and mixed traffic compared to walking and cycling, bus and rail corridors: SLOCAT Partnership (2018) Corridor Capacity tweet.

Sufficient action to scale down and shift personal travel to walking, cycling and public transport is laid out in 'Zero Carbon Britain – Rethinking the Future'.[40] However, the biggest shift must be around the transportation of goods. Both freight volumes and distances should be reduced.

The 'Trade and Investment Requirements for Zero Carbon' report highlighted the extent to which much of the current trade in goods is avoidable or unnecessary.[41] For instance, 21% of UK trade transport emissions are for fossil and biomass fuels, whose elimination is required to reach zero carbon and would alone represent a big dent in transport emissions. Additionally, if materials used in consumer goods and construction were reduced by half and used for twice as long, a 75% reduction in tonne-km could be possible.[42] Increasing UK food sufficiency and seasonality, and lowering meat consumption, would also change transport patterns, enabling a shift to far more regional and local distribution. We propose road usage to reduce by at least 60% and a modal shift to electrified rail freight for as much long-distance freight as possible.[43] The following target modal splits are therefore proposed (see **Tables 3** and **4**), which would result in changes to freight volumes and modal splits as set out in **Figure 2**.

Air	0 t-km
Road	580 t-km
Railways	490 t-km

Table 3. Proposed annual 2030 modal split – freight transport per person

Note: t-km = 1 tonne of goods transported 1 km.

Air	0 p-km
Cars	6,100 p-km
Buses/Coaches	1,300 p-km
Railways	1,900 p-km
Cycling	260 p-km
Walking	480 p-km

Table 4: Proposed annual 2030 modal split – passenger transport per person

Note: p-km = 1 passenger traveling 1 km.

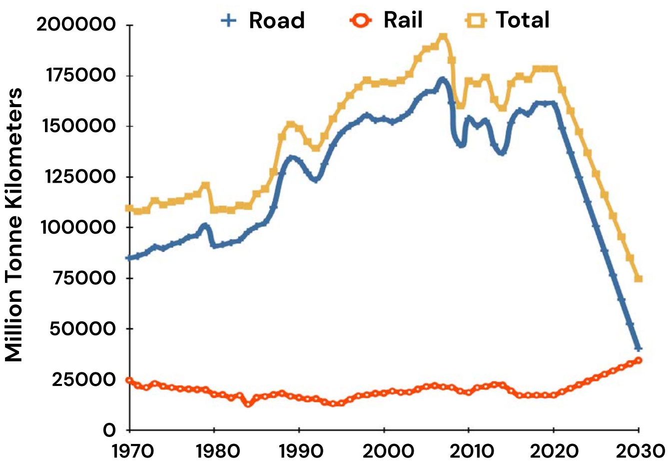

Figure 2: Past and modelled tonne/km of freight transportation trends

Sources: OECD (2020) 'Freight transport (indicator)'. DOI: 10.1787/708eda32-en (accessed Nov 2020).

Note: 2019–2020 assumed no change from 2018, and 2021–2030 required trend to zero carbon scenario.

40 Allen, P, et al (2013) 'Zero Carbon Britain: Rethinking the Future', *Centre for Alternative Technology* (CAT).

41 Sims, P, and Essex, J (2020) 'Trade and Investment Requirements for Zero Carbon'.

42 As proposed by Allwood, J, et al. (2019) 'Steel Arising: Opportunities for the UK in a Transforming Global Steel Industry', *University of Cambridge*.

43 A 50% increase in rail freight over seven years is proposed by Stephen Joseph Associates (2019) 'What level of ambition is achievable and worthwhile for rail freight?' *Rail Freight Group*. This would be economically viable with increase road pricing (e.g. fuel duty escalator, distance-based HGV road pricing or, alternatively, a Carbon Tax escalator). This report assumes that a transformative transition to zero carbon in ten years could increase railway freight by twice this. Network Rail predicted that with a 27% increase in HGV fuel costs and internalising of externalities imposed on society by both road & rail freight (Scenario F) there could be demand for increase of 119% by 2033 – see Network Rail (2019, revised August 2020) 'Rail freight forecasts: Scenarios for 2033/34 & 2043/44'.

Sufficient Action

Sufficient action by governments of all levels requires progress to be measure against annual rates of change required, not just focusing on distant end-point targets. **Table 5** below outlines examples of such rates of change that would represent a speed of transition in line with the UK making a sufficient contribution to limiting global temperature rise to 1.5°C. The meaning of 'sufficient' here, as discussed above, is based on getting to zero carbon using only proven technologies. It also means a precautionary and fair approach to emissions budgets, by taking consumption-based emissions totals, and considering historic emissions as well as current per-citizen emissions to determine its share of the global carbon budget.[44]

Sector	Rate of Change		Units
Energy Generation	**2014–2019**	**2020–30**	
Natural gas fuel use	+22	-83	Change in annual TWh
Onshore wind generation	+0.5	+4	GW installed per year
Offshore wind generation	+1.0	+14	GW installed per year

Sources: BEIS (2020) 'Digest of United Kingdom Energy Statistics (DUKES) 2020: dataset' – Natural gas, Table 4.1; Wind, Table 5.12.

Notes: Assumes 95% Natural Gas use reduction from 2019 levels over ten years. Takes renewable energy generation infrastructure proposals outlined in Table 2 and assumed a ten-year transition.

Steel Production	2015–2020	By 2025	
Electric arc furnace capacity	+0.4	+5.7	Megatonnes of annual production capacity
Coal-fired blast furnace capacity	0	-5.7	Megatonnes of annual production capacity

Notes: There hasn't been a significant change to UK steel furnace capacity since Teesside steel work closed its blast furnace just over five years ago.[45] Liberty Steel refurbished and brought back into operation it's second electric arc furnace Rotherham with an annual production capacity of 400,000 tonnes of steel.[46] Another 13 such electric arc furnaces would be needed to produce 5.7 Mt of recycled steel annually.

Freight Transport	2014–2019	2020–30	
Air freight	+0	-0.7	Billion tonne-km per year
Road freight	+5.2	-12	Billion tonne-km per year
Railway freight	-1.1	+1.7	Billion tonne-km per year

Source: Air freight: Civil Aviation Authority (n.d.) 'Airline data', 2014–2019 – tonnes used includes mail and freight.

Road freight: Department for Transport (2020) 'National Statistics: Road freight statistics: 2019' – Table RFS0104: 'Goods lifted by commodity'. Railway: Office of Road and Rail (2020) 'Freight rail usage and performance – Table 1310: Freight moved'.

Notes: Ten-year transition to modal split outline in Table 3.

44 Jackson, T (2019) 'Zero Carbon Sooner', CUSP Working Paper 18, *CUSP*.
45 BBC (2015) 'SSI Redcar steelworks to be shut' (accessed Nov 2020).
46 Sandoval, D (2018) 'Liberty Steel restarts furnace at UK mill', Recycling Today (accessed Nov 2020).

Passenger Transport	2014–2019	2020–30	
Air travel	+0.19	-0.44	Annual flight / person per year
Cars	-18	-400	Annual km / person per year
Public transport	+18	+160	Annual km / person per year
Walking and cycling	+3.7	+33	Annual km / person per year

Source: Cars, Public Transport, Walking & Cycling: Department for Transport (2020) 'National Travel Survey: 2019 data tables' (Table nts0303). Aviation based on Department for Transport and CAA (2018, updated 2019) 'Aviation statistics: data tables (AVI)' (Table AVI0101: Air traffic at UK airports).

Notes: Ten-year transition and modal split outline in Table 4.

Table 5: Example rate of change targets for measuring Sufficient Action

Our Government and Society must...

To take **Sufficient Action** (see above) to make sure we have the right infrastructure for zero carbon, our government and society must:

- Assess and target annually the required rates of change
- Stop **Choosing the Wrong Scale** for investment and letting **False Horizons** distract us
- Enable **Government Sets Direction**, manage demand and put **Public Money into Public Goods** so that our economy can **Investing in What We Already Have**.

These challenges form part of Green House Think Tank's zero carbon trade and investment toolkit.[47]

Choosing the Wrong Scale

The biggest blocker to a zero carbon world is the extent to which energy, materials and people are transported around our country and the world. We are simply **Choosing the Wrong Scale**.

Shrinking our material and carbon footprints means changing not just our production and consumption, but the nature of our connections to others, as our economies become more local. In many cases changing the scale will change the nature of production processes as the economy is reshaped from linear supply chains, often spanning the globe, to more local circular economies. This must extend from increased regional food sovereignty, reuse and remanufacturing,[48] to lower energy demand and renewable energy generation, to smaller-scale land-use, infrastructure and industrial production. But to be realised such initiatives require trade policies to reflect, rather than dictate, industrial, agricultural and climate policies.

POLICY RECOMMENDATION:

- Infrastructure scale for production and supply chains should be based on local or regional needs that are compatible with a zero carbon society.

47 Green House Think Tank (2020) 'Enablers and Blockers of Zero Carbon: Policy Toolkit'.

48 Zero Waste Scotland (2014) 'Reuse and Repair Centres/Hubs' and Lavery, G (2013) 'The Next Manufacturing Revolution: Non-Labour Resource Productivity and its Potential for UK Manufacturing', *Next Manufacturing Revolution*.

False Horizons

Our society must avoid the temptation of short-term solutions or long-term mirages that offer only an illusion of change.

Notable false horizons are Carbon Capture and Storage (CCS) and bioenergy (although biogas/bio-methane from anaerobic digestion of waste is an exception).

Commercial-scale CCS is unlikely to be a viable option in the next few decades and post-combustion carbon capture technologies has so far not even captured a majority of the CO_2.[49]

The combination of CCS with bioenergy (BECCS) is another false horizon. The UK doesn't have enough land to sustainably produce biomass at any significant scale, and global appropriation of biomass is already pushing up against planetary boundaries.[50] Yet the UK government subsidises the import and burning of more timber that the entire UK's forestry production.[51,52] BECCS underpins most national plans to decarbonise, as well as all but the most ambitious carbon reduction trajectories by the International Panel on Climate Change.[53]

The only proven and ecologically viable way of getting to zero carbon is to stop burning fossil fuels, and that requires focusing on reducing the scale of resource and energy consumption first.

POLICY RECOMMENDATIONS:

- CCS should be treated as an option of last resort rather than plan A.
- BECCS is not viable for the UK and there is very limited ecological capacity for it globally.
- Efficiency improvement polices need to be linked to **Reducing Demand** overall.
- Hydrogen infrastructure and demand need to be aligned with hydrogen production from renewable energy. Hydrogen produced from fossil fuels is not zero carbon compatible.[54]

Public Money for Public Goods

The government must take back control of and reform investment decision-making. It cannot be assumed that what maximises profit for private investors, even with strong regulatory change, is necessarily in the best interests of planet or wider society. Governments must both redirect public investment and constrain private investment that does not further zero carbon goals.

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49 IRENA (2019, 'Hydrogen: A Renewable Energy Perspective') noted that two flagship power plant CCS projects in the US and in Canada currently remove a little over 30% of CO_2 emissions. Additionally, a study comparing different systems of hydrogen production found that the plants studied captured between 53–90% of CO_2, meaning that between 10–47% still escaped into the atmosphere (Collodi, G, et al. (2017) 'Techno-economic Evaluation of Deploying CCS in SMR Based Merchant H2 Production with NG as Feedstock and Fuel', *Energy Procedia* 114, pp.2690–2712).

50 Allwood, J, et al. (2019), 'Absolute Zero: Delivering the UK's Climate Change Commitment with Incremental Changes to Today's Technologies', *UK FIRES*, p.13, Box 'What's the problem with bio-energy?'

51 The UK's Drax power station was subsidised £790m in 2019 for this. See Biofuelwatch (n.d.) '#AxeDrax Campaign' (accessed Oct 2020).

52 See Sims, P, and Essex, J (2020) 'Trade and Investment Requirements for Zero Carbon', p.14, Biomass story.

53 See IPCC (2018) 'Summary for Policymakers', in *Global Warming of 1.5°C. An IPCC Special Report*, p.14. All but the first pathway include bioenergy with carbon capture and storage (BECCS).

54 Fischer, L (2020) 'E3G submission: EAC inquiry into hydrogen', *E3G*.

The nature of a 'public good' needs to be redefined beyond immediate national interest to take account the interests of future generations and the other life we share the Earth with. Public funding must stop supporting infrastructure and other fixed capital assets that do not fit within national carbon budgets. Similarly, sufficient planning policies and enforcement, and rules governing private enterprises, must ensure that the impacts of corporate decisions are also reflected in national carbon budgets.

This would prohibit public funding for waste incinerators, road capacity expansion, and coal, oil and gas exploration and production. Infrastructure investment would then be restricted to that which delivers a rapid *energy return on energy invested and emissions reduction relative to embodied emissions*. For example, the energy embodied by new solar PV and wind turbines is quickly recovered.[55] The focus must be on investment that delivers demand reduction to achieve a short-term (climate) payback.

POLICY RECOMMENDATIONS:

- Government needs to subsidise, or directly commission, infrastructure required for zero carbon.
- Decision-making that governs public investments must require all projects to fit within national carbon budgets (including direct and indirect emissions).[56]
- We should not continue to invest in infrastructure that supports sectors of the economy that cannot yet be decarbonised with current technologies (e.g. aviation, shipping).

Government Setting Direction

Government must set direction for infrastructure investment. There is ample evidence that when government fails to lead, either nothing changes or things drift in the wrong direction. Too often government fails either to set targets or to devise a plan to meet targets, reducing targets to political greenwash. For example, consider how government and business leaders talk up the need for zero carbon homes: until the government sets mandatory zero carbon in use standards and properly **Taxing Harm** (including greenhouse gas emissions) associated with building materials, new houses will continue to have high embodied emissions.

POLICY RECOMMENDATIONS:

- Government must put in place legislation and regulations that create a clear direction of travel – for example, setting out which technologies or fuels should replace natural gas for heating or diesel for HGVs.
- Government must *lead structural changes to industrial production*, to ensure that they happen quickly.
- Government must empower and resource local communities to *deliver a just transition* that retrains and re-employs workers from high-carbon sectors.
- Government must set a *clear overall economic strategy* which lays out the nature and scale of infrastructure, production and consumption that is in line with a zero carbon society.

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55 Wu, P, et al. (2017, 'Review on life cycle assessment of energy payback of solar photovoltaic systems and a case study', *Energy Procedia* 105, pp.68–74) found a two-year energy payback. Bonou, A, et al. (2016, 'Life cycle assessment of onshore and offshore wind energy-from theory to application', *Applied Energy* 180, pp.327–337) found energy paybacks to be less than one year.

56 Such as in cost-benefit analysis, environmental impact assessment, strategic environmental assessment and sustainability appraisal and in particular the UK government's Green Book, (see Asking the Wrong Questions in the Sims and Essex (2020) Trade and Investment Requirements for Zero Carbon.)

- All infrastructure investment must be (via planning system) fully budgeted for within national (as well as local) carbon budgets (including both direct as well as indirect emissions).
- Local, regional and national governments must plan and lead delivery of infrastructure and building retrofit to ensure sufficient rate of change.

Investing in What We Already Have

We need to prioritise maintaining and upgrading existing infrastructure over creating new infrastructure. This means shifting investment away from infrastructure growth to free up the finance and resources required to decarbonise our *existing* built environment. For example, retrofitting or reclamation and reuse of existing buildings, rather than demolition and redevelopment, will dramatically reduce the need for carbon intensive materials (e.g. concrete, bricks, steel) as the superstructures and foundations are retained.

Investing in what we already have needs to apply to domestic and commercial goods and equipment as well as infrastructure and buildings. This will not only reduce the need for manufacturing materials and energy, but globally it will free up a lot of manufacturing infrastructure. For individuals, this investing means keeping clothes, furniture and electronic items for longer, and adapting, repairing and upgrading them. This will support the development of local circular economies in repair, tailoring and renovation, which in turn increases community self-reliance.

POLICY RECOMMENDATIONS:

- Shift investment from construction of new buildings towards decarbonising the existing built environment through retrofitting.
- Tax resource extraction and fossil fuel energy use (see **Taxing Harm**)[57] so the full costs are apparent.
- Exempt repair and renovation from VAT.

57 See Sims, P, and Essex, J (2020) 'Trade and Investment Requirements for Zero Carbon', Table 1.

Responding to the climate emergency means making different infrastructure choices. It means reducing demand for energy and materials, and installing renewable energy faster. This report uses a toolkit of blockers and enablers to examine what sufficient change would look like in three key sectors: transport, energy and steel.

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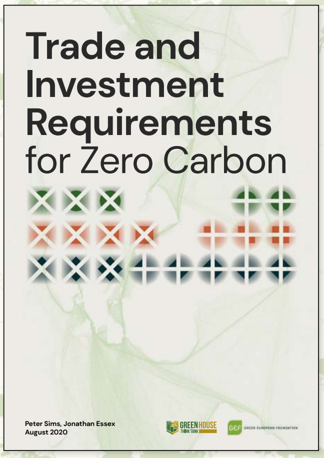

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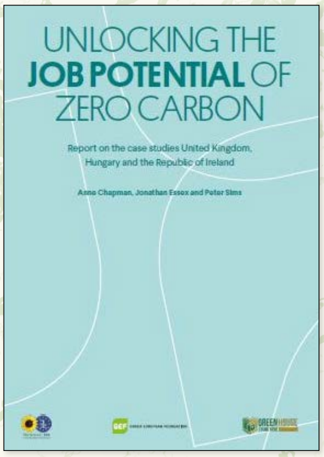

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