NAVIGATE

Next generation of advanced integrated assessment modelling to support climate policy making

Long-term impacts of COVID-19 on energy use in transport and buildings

Results from the NAVIGATE project

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Reducing energy demand for transport and buildings is critical for reaching net-zero

Transport accounts for 34% of EU final energy consumption, rising by 11% over the period 2000-2018 (JRC 2020). Homes account for 25% of final energy, falling by 15% over the same period. The direct use of energy in transport and buildings accounts for 42% of the EU's territorial carbon emissions excluding waste and land use (EEA 2019). Reducing energy use through structural improvements in energy efficiency and more efficient forms of service provision is a critical strategy for meeting net-zero targets in line with the EU's Green New Deal (Grubler et al. 2018; Tsiropoulos et al. 2020).

Energy use has three drivers or components: *activity* (A), *structure* (S), and *intensity* (I).[1] These three drivers are widely used in energy-demand modelling and analysis (Creutzig et al. 2015; IEA 2020b; Schipper et al. 1992). *Activity* describes the amount of useful energy services consumed - e.g., passenger-kilometres travelled (in the case of mobility), and m^2 of heated or cooled floorspace (in the case of thermal comfort). *Structure* describes the mix of technologies or options used to provide those services - e.g., cars, bicycles, buses, trains (mobility), and gas boilers, heat pumps, and other heating, ventilation and air conditioning 'HVAC' systems (thermal comfort). *Intensity* describes the energy efficiency of each technology or option - e.g., vehicle fuel efficiency (mobility), and HVAC efficiency or heat pump coefficient of performance (thermal comfort).

COVID-19 and resulting policies have impacted energy use in transport and buildings

Lockdown measures and other COVID-19 restrictions have clearly impacted transport-related activity in particular, but also the shares and types of activity in residential and commercial buildings. 'Enforced confinement' in countries around the world has in turn had major short-term effects on energy use and carbon emissions in 2020 (Guan et al. 2020; Le Quéré et al. 2020). The *activity-structure-intensity* (A-S-I) decomposition helps capture more specific impacts of COVID-19 on energy demand.

In transport, overall *activity* fell sharply during lockdowns, with extreme reductions in public transport ridership and aviation. Reduced transport activity has even been felt in a 'global quieting' of seismic noise (Lecocq et al. 2020). The *structure* of passenger transport has also changed, with a substitution of public and shared modes by private vehicle use and active modes (ITF 2020). Some areas have reported traffic levels back up to, or exceeding pre-lockdown levels (IEA 2020a). There is limited evidence yet of any changes in *intensity* as this is associated with capital stock turnover.

In buildings, overall *activity* has shifted from offices and retail to homes. Half-hourly smart gas meter data shows an increase in home heating activity throughout the day given higher occupancy levels (Octopus Energy 2020). However the first wave of European lockdowns occurred during a mild spring so major impacts on energy used for thermal comfort are not yet evident. As buildings are generally tied to a single heating or cooling system with decadal replacement cycles, there are no clearly observed changes yet in the *structure* or *intensity* of thermal comfort.

Energy demand in buildings is also for powering devices and appliances including: information and communication technologies (ICTs); appliances for domestic functions and routines (e.g., cooking, cleaning, lighting); and home-entertainment and luxuries (e.g., home cinemas, patio heaters). Overall *activity* has similarly shifted from offices to homes, with an accompanying shift in *structure* towards ICTs (McKinsey 2020). There is no evidence yet of a change in *intensity* through efficiency upgrades in residential appliances.

[1] The same A-S-I acronym also usefully captures the main strategies for reducing energy use: avoid (A), shift (S), improve (I) (Creutzig et al. 2018). Avoid strategies seek to reduce the amount of energy service consumed ('do less'). Shift strategies seek to change the structural mix of technologies or options used to provide the energy service ('do differently'). Improve strategies seek to improve the energy and material efficiency of those technologies and options ('do more efficiently').

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The enduring impacts of COVID-19 on energy use in buildings and transport remain highly uncertain.

Short-term effects of COVID-19 are observable and evidenced in travel, electricity, gas and other data. Whether these effects will persist is uncertain. Taking the EU as an example, uncertainties about COVID-19's enduring impacts include:

- *social uncertainty*: Will the social learning and experiences from lockdowns become embedded in new patterns of daily living, working, and travelling? Or will the impulse to restore the familiarity of pre-lockdown normality prevail? (Boons 2020)
- *policy uncertainty*: Will stimulus packages and public policies target and support more resource-efficient activity in buildings and transport? Or will state-led recovery efforts stimulate a rapid intensification of economic activity without regard to energy use? (IEA 2020c; Vivid Economics 2020)
- *convergence uncertainty*: Will different regions and countries in Europe show similar social, institutional and policy responses to COVID-19? Or will different areas navigate their own paths in response to particular circumstances and competitive advantages? (Schumacher 2020)
- *inequality uncertainty* - Will economic recession and adverse impacts of COVID-19 on specific income and employment groups lead to greater heterogeneity in end-use activity? Or will society's collective response to COVID-19 shocks strengthen as economies recover?

Scenario analysis is a useful scientific tool for systematically exploring these uncertainties to identify robust policy decisions. Such studies are starting to appear, though with a limited set of tools and assumptions (Dafnomilis et al. 2020; Forster et al. 2020). Scenario analysis can also be used normatively to set out pathways aligning economic recovery with decarbonisation to net-zero (Barbier 2020; IEA 2020c). There are many such studies currently being published.

Given current uncertainties, we have designed a monitoring framework to track which impacts on energy use persist during the recovery from COVID-19.

The enduring impacts of COVID-19 on energy use in buildings and transport should become clearer and observable over the next 12-18 months. Why? First, immediate adaptive responses to the shock will have had time to settle into more planned resilience strategies, boosted by recent news of effective vaccines. Second, stimulus packages and other policy measures will have had time to take effect. Third, impacts on the rate and type of capital stock turnover will start to become visible (e.g., new car and appliance sales). Fourth, behaviour and social interaction will be less conditioned by health risk responses.

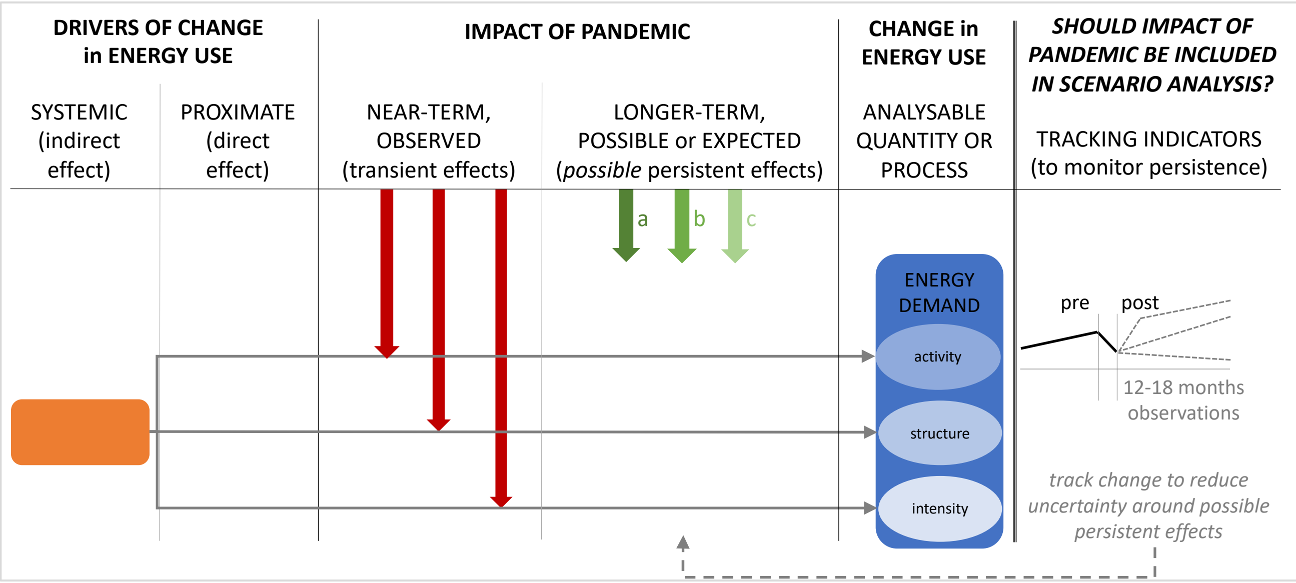
Monitoring the enduring impacts of COVID-19 over the next 12-18 months should therefore help reduce salient uncertainties and establish a robust evidence base for scenario analysis. The EU H2020-funded 'NAVIGATE' project is developing state-of-the-art energy-demand modelling techniques which will be applied to post-COVID-19 futures once this evidence base is established.

Our monitoring framework is represented schematically in Figure 1. The monitoring framework is designed to:

- capture the impact pathways through which COVID-19 has changed the *activity*, *structure* and *intensity* of energy use;
- distinguish impact pathways caused by societal or economy-wide effects from more proximate or direct effects of COVID-19 on energy use;
- set out expectations for possible enduring impacts of COVID-19 on energy use based on evidence to-date, expert judgement, and relevant theories of change;
- identify indicators and data sources for tracking actual impacts over the next 12-18 months;
- be adaptable to emerging evidence which reduces current uncertainties by making some impact pathways irrelevant while potentially introducing other unanticipated impact pathways;

- be open to critical review, stakeholder input, and crowd-sourcing of impact pathways and indicators (citizen science).

FIGURE 1: OUR MONITORING FRAMEWORK IDENTIFIES INDIRECT (SYSTEMIC) AND DIRECT (PROXIMATE) EFFECTS OF THE PANDEMIC ON ENERGY USE, AND IDENTIFIES INDICATORS FOR TRACKING WHICH OF THESE IMPACT PATHWAYS PERSISTS OVER THE NEXT 12-18 MONTHS.

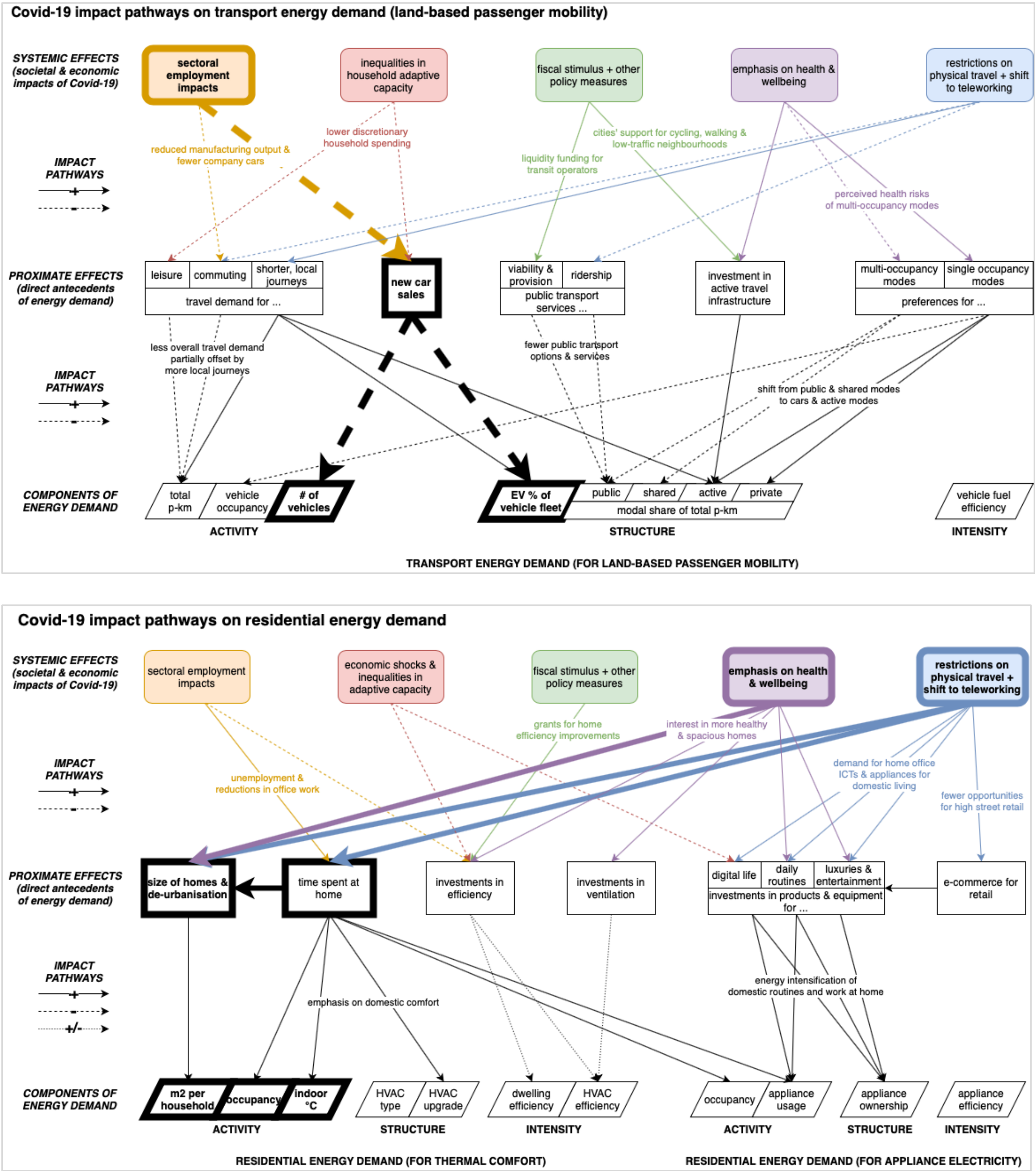


Our monitoring framework distinguishes five systemic effects of COVID-19 and a wide range of proximate effects of COVID-19 on energy use.

COVID-19 has had major systemic effects on economic performance, sectoral activity, industrial output, supply chains, physical movement, digitalisation, social norms, and much more. We have included five of these systemic effects in our monitoring framework (see upper part of Figure 2). Each of these systemic effects is having an impact, or may have an enduring impact on energy use:

- *sectoral employment impacts:* sharp downturn and redundancies in some sectors (e.g., hospitality, physical retail, aviation) with unexpected growth in other sectors (e.g., e-commerce, digital services) (Schumacher 2020)
- *inequalities in household adaptive capacity*: differentiated responses to lockdown restrictions, impacts on livelihoods, and health risk exposure - all shaped by households' income, context, and geography (Weill et al. 2020)
- *fiscal stimulus + other policy measures*: massive fiscal support measures to support the economy through the COVID-19 shock and stimulus packages to boost employment out of short-term recessions (IMF 2020)
- *emphasis on health and wellbeing*: personal and cultural emphases on reducing health risks, supporting physical and mental wellbeing, and aligning social practices with healthy outcomes (Boumphrey 2020)
- *restrictions on physical travel + shift to teleworking*: rules and laws restricting physical movement, corporate policies supporting teleworking (home offices), and shifting preferences towards travel (IEA 2020a)

FIGURE 2. COVID-19 HAS HAD BOTH INDIRECT AND DIRECT EFFECTS ON ENERGY USE. IMPACT PATHWAYS (ARROWS) LINK SYSTEMIC EFFECTS (TOP) TO PROXIMATE EFFECTS (MIDDLE) TO THE ACTIVITY-STRUCTURE-INTENSITY COMPONENTS OF ENERGY USE (BOTTOM). IMPACT PATHWAYS DESCRIBE POSSIBLE ENDURING EFFECTS OF COVID-19 ON ENERGY USE (SOLID ARROWS DENOTE INCREASES, DOTTED ARROWS DENOTE DECREASES). UPPER AND LOWER PANELS SHOW IMPACT PATHWAYS FOR TRANSPORT AND RESIDENTIAL ENERGY DEMAND RESPECTIVELY, HIGHLIGHTING ONE IMPACT PATHWAY FOR ILLUSTRATIVE PURPOSES.



Our monitoring framework also includes more direct or proximate effects on energy use (see middle part of Figure 2). These proximate effects directly impact energy-related activity. For example, increased home occupancy directly increases activity levels for residential energy demand.

The impact pathways in our monitoring framework represent distinct causal mechanisms by which COVID-19 may have an enduring effect on energy use.

We have connected the systemic and proximate effects of COVID-19 to the *activity-structure-intensity* components of energy use through impact pathways (shown as arrows in Figure 2). Each impact pathway is a hypothesis or expectation about how COVID-19 may cause a persistent change in energy use (solid arrows indicate an expected increase, dotted arrows an expected decrease).

Using a combination of observed evidence to-date, proposed stimulus packages, expert judgement among the NAVIGATE team, and relevant theories of change, we have included a large number of impact pathways. Figure 2 highlights a few of these for illustrative purposes.

In the upper panel of Figure 2 for transport energy demand, sectoral employment impacts may adversely affect automotive manufacturing capacity and company car sales which in turn may slow the transition to electric vehicles (EVs) as fleet turnover slows.

In the lower panel of Figure 2 for residential energy demand, restrictions on physical travel and reduced commuting causing households to spend more time at home may interact with a health and wellbeing emphasis on access to green space and more domestic living space. This in turn may increase thermal comfort levels in larger homes.

We have identified a range of indicators and data sources for tracking the impact pathways in our monitoring framework to see which have an enduring effect on energy use over the next 12-18 months.

The main purpose of our monitoring framework is to establish a robust evidence base on the enduring impacts of COVID-19 on energy use. We will use this evidence base to inform our future scenario and policy analysis of net-zero pathways, accounting for structural changes in energy demand caused by COVID-19.

We do not know which of the many impact pathways shown in Figure 2 will prove persistent. However, we have identified a range of indicators with associated data sources for tracking what happens over the next 12-18 months. Over this period we expect the transient effects of COVID-19 to recede and enduring effects to become more clearly visible. This will enable us to reject some if not many of the impact pathways, while confirming others.

The indicators draw on publicly-available data sources reporting with reasonably short time delays. As examples for the highlighted impact pathways in Figure 2:

- whether *sectoral employment* has an enduring impact on *new car sales* can be tracked using quarterly economic activity data, automotive plant output data, company reports on car sales
- whether *new car sales* have an enduring impact on the *number of vehicles* and *EVs as a % of the vehicle fleet* can be tracked using car sales data, EV sales data, EV grant take-up, travel statistics
- whether *restrictions on physical travel + shift to teleworking* has an enduring impact on *time spent at home* and *size of homes* can be tracked using mobility apps, national travel statistics, company reports on teleworking, household surveys, property market data
- whether *time spent at home* has an enduring impact on *occupancy* and *indoor °C* (as a proxy for thermal comfort levels) can be tracked using smart meter data, household surveys, smart thermostat data

One important limitation of our monitoring framework is the difficulty of tracking variation between and within countries with a parsimonious set of indicators. In some cases, it is also difficult to identify reliable data sources providing close-to-real-time information. However, our set of indicators can grow and be refined through the monitoring period.

The impact pathways in our monitoring framework identify policy opportunities to embed beneficial effects and mitigate adverse effects of COVID-19 on energy use.

The impact pathways linking COVID-19's systemic and proximate effects to the *activity*, *structure* and *intensity* of energy use in buildings and transport also represent policy opportunities.

Policy interventions may seek to strengthen, support or embed an impact pathway that leads to a reduction in energy use. As an example from Figure 2, a fall in new car sales causing a reduction in the size of the vehicle fleet could be supported by a 'cash for clunkers' scrappage programme tied to EV purchase incentives.

Policy interventions may seek to weaken, mitigate or counteract an impact pathway that leads to an increase in energy use. As an example from Figure 2, more time spent at home causing higher occupancy rates in larger, warmer homes could be mitigated by home retrofit programmes and mass rollout of smart zonal heating systems to reduce heated floor areas.

The impact pathways in our monitoring framework collectively represent a theory of change for how COVID-19 may have enduring effects on energy use. As such, it is open to adaptation, improvement and critique.

References

Barbier EB (2020) Greening the Post-pandemic Recovery in the G20 Environmental and Resource Economics 76:685-703 doi:10.1007/s10640-020-00437-w

Boons F, Browne, A., Burgess, M., Ehgartner, U., Hirth, S., Hodson, M., Holmes, H., Hoolohan, C., MacGregor, S., McMeekin, A., Mylan, J. Oncini, F., Paterson, M., Rödl, M., Sharmina, M., Warde, A., Welch, D., Wieser, H., Yates, L., Ye, C. (2020) COVID-19, changing social practices and the transition to sustainable production and consumption. Sustainable Consumption Institute., Manchester, UK

Boumphrey S (2020) How will consumer markets evolve after coronavirus? Euromonitor International,

Creutzig F, Jochem P, Edelenbosch OY, Mattauch L, Vuuren DPv, McCollum D, Minx J (2015) Transport: A roadblock to climate change mitigation? Science 350:911-912 doi:10.1126/science.aac8033

Creutzig F et al. (2018) Towards demand-side solutions for mitigating climate change Nature Climate Change 8:268-271 doi:10.1038/s41558-018-0121-1

Dafnomilis I, Elzen Md, Soest Hv, Hans F, Kuramochi T, Höhne N (2020) Exploring the impact of the COVID-19 pandemic on global emission projections: Assessment of green versus non-green recovery. PBL Netherlands Environmental Assessment Agency & New Climate Institute, The Hague, The Netherlands

EEA (2019) EU greenhouse gas emissions by aggregated sector. European Environment Agency (EEA), Copenhagen, DK

Forster PM et al. (2020) Current and future global climate impacts resulting from COVID-19 Nature Climate Change doi:10.1038/s41558-020-0883-0

Grubler A et al. (2018) A Low Energy Demand Scenario for Meeting the 1.5oC Target and Sustainable Development Goals without Negative Emission Technologies Nature Energy 3:515-527 doi:DOI.org/10.1038/s41560-018-0172-6

Guan D et al. (2020) Global supply-chain effects of COVID-19 control measures Nature Human Behaviour 4:577-587 doi:10.1038/s41562-020-0896-8

IEA (2020a) Changes in transport behaviour during the COVID-19 crisis. International Energy Agency, Paris, France

IEA (2020b) Energy Efficiency Indicators 2020. International Energy Agency, Paris, France

IEA (2020c) Sustainable Recovery: World Energy Outlook Special Report. International Energy Agency, Paris, France

IMF (2020) Policy Tracker: Ecomomic responses to COVID-19 by 196 countries. International Monetary Fund, Washington, DC

ITF (2020) Re-spacing Our Cities For Resilience. International Transport Forum (ITF), Paris, France

JRC (2020) Energy Consumption and Energy Efficiency trends in the EU-28, 2000-2018. Joint Research Centre (JRC), Brussels, Belgium

Le Quéré C et al. (2020) Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement Nature Climate Change doi:10.1038/s41558-020-0797-x

Lecocq T et al. (2020) Global quieting of high-frequency seismic noise due to COVID-19 pandemic lockdown measures Science 369:1338 doi:10.1126/science.abd2438

McKinsey (2020) Across Europe, engagement with industries through online channels has increased by an average of 13%. McKinsey & Company COVID-19 Digital Sentiments Insight, San Francisco, CA

Octopus Energy (2020) Energy consumption under social distancing measures.

Schipper L, Steiner R, Duerr P, An F, Strom S (1992) Energy use in passenger transport in OECD countries: Changes since 1970 Transportation 19:25-42

Schumacher I (2020) Perspectives on the Economics of the Environment in the Shadow of Coronavirus Environmental and Resource Economics 76:447-517 doi:10.1007/s10640-020-00493-2

Tsiropoulos I, Nijs W, Tarvydas D, Ruiz P (2020) Towards net-zero emissions in the EU energy system by 2050: Insights from scenarios in line with the 2030 and 2050 ambitions of the European Green Deal. Joint Research Centre (JRC), Brussels, Belgium

Vivid Economics (2020) Greenness of Stimulus Index.

Weill JA, Stigler M, Deschenes O, Springborn MR (2020) Social distancing responses to COVID-19 emergency declarations strongly differentiated by income Proceedings of the National Academy of Sciences 117:19658 doi:10.1073/pnas.2009412117

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