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LETTER

Existing infrastructure and the 2°C target

A Letter

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Abstract To clarify the link between existing infrastructure legacy and the 2°C target, we extend the work of Davis et al. (Science 329:1330–1333, 2010) by introducing non-CO_2 greenhouse gases and the inertia in transportation-needs drivers. We conclude that climate policies able to maintain climate change below 2°C cannot disregard existing infrastructure.

In a recent article entitled "Future CO2 emissions and climate change from existing energy infrastructure" Davis et al. (2010) address the important issue of the climate change inertia created by existing infrastructure. Their methodology quantifies the legacy of existing energy infrastructure in terms of future CO_2 emissions and climate change. Their paper concludes that existing energy infrastructure commits us to a mean warming of 1.3°C (1.1°C to 1.4°C, depending on assumptions) in 2060, and that "*the sources of the most threatening emissions have yet to be built*".

It seems unavoidable that readers parallel their "mean warming of 1.3°C" and the political icon of the 2°C target, which was again recognized by the 16th Conference of the Parties (COP) to the UNFCCC. Indeed, results from Davis et al. (2010) could easily, but erroneously, lead to the conclusion that the climate policies needed to reach the 2°C target can disregard existing infrastructure and focus on what is still to be built.

This letter clarifies the possible interpretations of Davis et al. results in terms of climate policy. It argues that the analysis by Davis et al. cannot conclude on the need to address existing infrastructure to reach the 2°C target, because it is limited to CO_2 and to infrastructure that *directly* emits CO_2. The latter point is important because non-emitting infrastructure – like roads and urban forms – creates an additional inertia on future emissions, by influencing energy demand and implementable technologies.

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We propose an extension of the Davis et al. methodology that accounts for other greenhouse gases (GHG) and for infrastructure that does not itself emit CO2, but perpetuates a global economy which does. Our approach suggests that climate policies able to maintain climate change below 2°C above pre-industrial temperatures cannot disregard existing infrastructure and need to act also on behaviours and existing capital early retirement or retrofit.

To demonstrate this point, we introduce (i) the inertia in assets location and energy-services demand drivers in the transportation sector, while the initial analysis only accounts for energy-services supply inertia; and (ii) the role of non-CO_2 GHG.

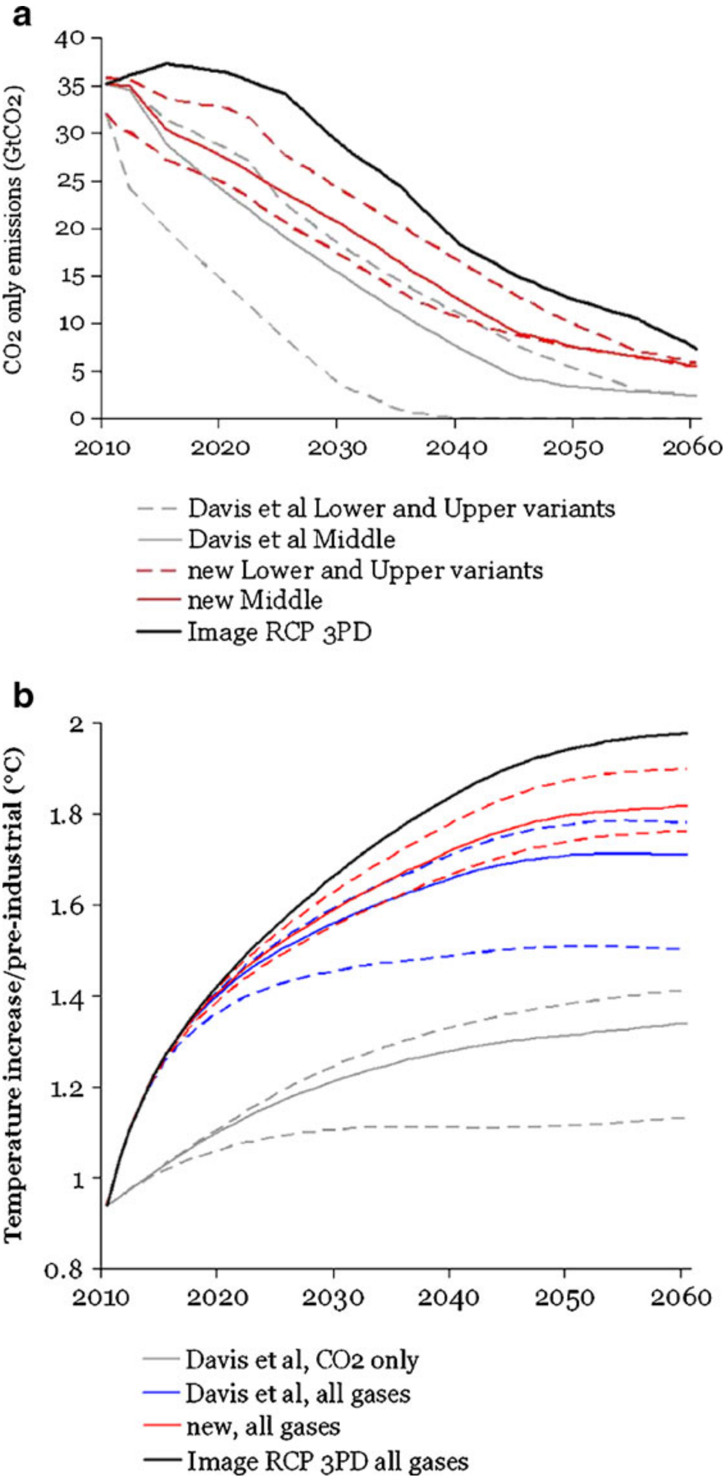
Considering only capital that directly emits CO_2, Davis et al. investigate the inertia in the supply of energy services. To quantify the inertia in GHG emissions caused by installed capital, their methodology has to be extended to also account for the inertia in demand, which is linked to infrastructure and installed capital, including its location. For instance, building shells condition over the long-term the energy demand for heating and cooling. Assets location, including urban forms and transport infrastructure location, determine mobility needs. Transport infrastructure also influence choices between alternative transport modes with different emission intensity (e.g., personal vehicles vs. public transport). Given the lifetimes of buildings and transport infrastructures, and the even larger inertia of urban forms (Jaccard and Rivers 2007; Gusdorf et al. 2008), energy-services demand inertia might be a stricter constraint on energy services production than installed supply capital.

We illustrate the effect of this additional inertia through the example of transport. Starting from the three emissions scenarios from Davis et al. (lower; middle; and upper), we modify the emissions due to the transportation sector. In the original analysis, only the existing fleet of vehicles is taken into account; beyond the lifetime of this fleet, emissions from transport is reduced to zero, as if other existing infrastructure (e.g., roads, railways, buildings and other asset locations) were not constraining these emissions in the future. We claim that transport infrastructure and assets locations create an additional inertia on transport emissions, which is larger than the inertia of the vehicles fleet.

Our methodology, detailed in the Supplementary Online Material (SOM), can be summarized as follows: we assume that mobility needs are determined by assets location, and that existing assets relocation is impossible. We also disregard modal shifts, assuming for instance that a road that is built will be used over its entire lifetime, constraining personal vehicle use. We thus assume constant mobility needs for each transport mode. With these assumptions, future CO_2 emissions depend mainly on the evolution of transportation fleet technologies, which cannot allow for immediate and complete decarbonisation. We retain the same assumptions as Davis et al. for vehicles lifetimes and we use new vehicles market shares from the International Energy Agency BlueMap scenario (IEA 2009), an optimistic scenario in terms of technical change in the transportation sector.

We find that these assumptions lead to a much larger commitment to CO_2 emissions (Fig. 1, left panel) and global temperature increase (Fig. 1, right panel), than in David et al. For instance, emissions inherited from existing capital are 35% higher in 2030 and 134% in 2060 in our analysis, for the Middle scenarios. CO_2 emissions due to existing capital in our Upper scenario (see SOM) are even very close to those of the RCP 3PD scenario (19%

Fig. 1 **a** Scenarios of CO_2 emissions from existing infrastructure (The detail of transport related CO_2 emissions is given in the SOM) and **b** associated global mean temperature increases above pre-industrial level. The scenarios correspond to Davis et al. results, the new results from this article, and the Image RCP 3PD scenario for comparison purposes. Dashed lines indicate total CO_2 emissions and temperatures from upper and lower-bound scenarios


a
CO2 only emissions (GtCO2)
40
35
30
25
20
15
10
5
0
2010
2020
2030
2040
2050
2060
Davis et al Lower and Upper variants
Davis et al Middle
new Lower and Upper variants
new Middle
Image RCP 3PD
b
Temperature increase/pre-industrial (°C)
2
1.8
1.6
1.4
1.2
1
0.8
2010
2020
2030
2040
2050
2060
Davis et al, CO2 only
Davis et al, all gases
new, all gases
Image RCP 3PD all gases

below RCDP 3PD in 2025 and only 9% below in 2040), implying a risk of overshoot above the 2°C global temperature threshold (van Vuuren et al. 2007).

With these assumptions, the remaining "emission budget" for new generations of capital and increase in energy-services demand is thin if one wants to maintain climate change below 2°C above pre-industrial temperatures. For instance, the difference in emissions between the committed emissions in our upper scenario and the RCP 3PD is limited to 1.7 $GtCO_2$ in 2040. It means that following the RCP 3PD scenario – which is necessary to remain below the 2°C limit – requires to increase emissions in 2040 by no more than 10% over the emissions legacy due to existing infrastructure.

The same analysis could be carried out on building shells to assess the inertia in energy demand for heating and cooling needs. This addition would lead to even higher CO_2-emissions inertia due to existing infrastructure, but taking into account transport only is sufficient to suggest that existing infrastructure cannot be disregarded in climate policy designs.

Moreover, Davis et al. account only for the radiative forcing from CO_2, neglecting other GHG gases. But, in 2005, CO_2 were responsible for a radiative forcing of 1.69 W/m^2, while other GHG gases (CH4, N2O and halocarbons) represented a forcing of 0.98 W/m^2. The influence of other GHG gases is currently offset by a negative forcing from aerosols and O_3 (−0.77 W/m^2 in 2005), but their importance is likely to grow in the future as the masking effect from aerosols and O_3 is projected to decrease rapidly in the coming decades.

Taking other gases into consideration increases the difficulty of maintaining climate change below 2°C (see Fig. 1, right panel). To illustrate this point, we start from the Davis et al. analysis results and we include the non-CO_2 and aerosols radiative forcing from the scenario Image RCP 3PD (van Vuuren et al. 2007), i.e. from a scenario representative for emissions pathways leading to very low GHG concentration levels. In the Davis et al. Medium scenario, this additional forcing represents in 2020 an additional forcing of 21% with respect to the forcing from CO_2 only, and of up to 23% in 2040.

Taking into account both methodological extensions, namely the capital-related inertia in energy services demand and other GHG gases, it appears that the remaining emissions budget for the new capital to satisfy energy services demand from a larger and wealthier population is very thin, if we want to remain below the 2°C target. In our scenarios (accounting for inertia in transportation needs and non-CO_2 GHG and aerosols), the legacy from existing infrastructure and capital leads in 2060 to a warming of 1.71°C above pre-industrial level in the Middle scenario and 1.78°C in the Upper scenario. Since the Image RCP 3PD scenario is particularly optimistic and considering the large need for additional infrastructure in developing countries, these results show that reaching the 2°C target without capital retrofit or early retirement appears extremely difficult. Existing infrastructure will thus play a key role in the feasibility of this internationally recognized objective.

To give some room to the future energy services demand, action on existing capital and infrastructure appears necessary. Our results support the idea that climate policies acting solely on new energy supply and on technologies would not be sufficient to reach the 2°C goal. Surmounting the legacy of installed infrastructure is thus part of the climate challenge. To do so, it will be necessary to organize the early retirement or retrofit of some existing capital, to accelerate capital turnover and/or to target the drivers of energy services demand, and in particular modal shift and mobility needs linked to infrastructure and assets locations.

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