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Bauer, Fredric; Fontenit, Germain

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PO Box 117
221 00 Lund
+46 46-222 00 00

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Plastic dinosaurs – Digging deep into the accelerating carbon lock-in of plastics

Fredric Bauer [*], Germain Fontenit [1]

Environmental and Energy Systems Studies, Lund University, P.O. Box 118, SE-221 00, Lund, Sweden

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ABSTRACT

The continued expansion of plastics production all over the world entrenches modern societies and life styles deeper in the dependence on fossil resources. This research note develops the main aspects of the carbon lock-in in the plastics industry and how it extends into many aspects of contemporary life. With data collected from trade press and reports, we present insights of the investment trends in the plastics industry from the past decade. We show that among the twelve largest companies 88 new projects for production capacity increase and infrastructure expansion were announced between 2012 and 2019. We connect this increasing infrastructural lock-in to actions and strategies enacted by the industry to restrict regulations on the use of plastics and support specific consumer behaviour to uphold also an institutional and behavioural lock-in. The paper outlines the need for more extensive research on the plastics and petrochemical sectors, especially regarding data from Asian companies and activities in China in particular. We also point to areas of grave concern for new policy, aiming to reduce the high growth rate for the volumes of oil and gas that feed the industry as the current focus on plastic waste collection and recycling is insufficient.

1. Introduction

The seminal paper on carbon lock-in by Unruh published in this journal 20 years ago (Unruh, 2000) provided a much-needed interdisciplinary understanding of how the complex constituted by interlinked infrastructures, technologies, norms, policies, and institutions supports our dependence on fossil resources and creates a strong inertia against most forces aiming to break free from it. The concept of carbon lock-in has supported interdisciplinary research as it connects key concepts from different research traditions to close in on one of the most pressing challenges of modern societies. While economists previously discussed positive feedbacks due to economies of scale, learning, and network (Arthur, 1994), science and technology scholars elaborated on the power of large technical systems (Hughes, 1983), and transition researchers discussed the inertia of technological regimes (Rip and Kemp, 1998) the concept of carbon lock-in managed to create a middle-ground for exchanging knowledge and perspectives on barriers to the necessary energy system transformation. While global demand for coal has since levelled out, demand for oil and gas has steadily increased and are projected to continue doing so (IEA, 2019) – the decrease in demand due to the covid-19 pandemic is likely to be as transient as the decrease during the financial crisis of 2008–2009. Global efforts to mitigate climate change through international and domestic policy initiatives have thus not successfully challenged the lock-in – which rather has been globalized and captured also developing economies, as foreseen by Unruh and Carrillo-Hermosilla (2006).

Research and reporting published in the past few years has increased the understanding of how oil and gas companies have continued to profit from the lock-in and promote its extension; strategizing to continue producing the fossil fuels that break down the climate for as long as possible, in the end counting on compensation to stop, and then profiting off the transition (Harris, 2020). The explosive growth of fracking and shale gas production in the US in the 2010’s was an outcome of strategic investments in a continued carbon lock-in, manifested in infrastructures and global markets (Middleton et al., 2017; Wang and Krupnick, 2015). Less attention has however been paid to how other groups of actors are not only caught in the carbon lock-in but actively continue to reinforce and strengthen it.

The pursuit of a continued carbon lock-in occurs across the domains of infrastructure and technology, institutions, and behaviour (Seto et al.,

* Corresponding author.
E-mail addresses: fredric.bauer@miljo.lth.se (F. Bauer), germain.fontenit@sei.org (G. Fontenit).
[1] Present address: Stockholm Environment Institute, Stockholm, Sweden.

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2016). Infrastructure and technology using and enabling the use of fossil fuels are material manifestations of carbon lock-in, and represent a concrete path dependency as actors who have invested in these technologies aim to capitalize on their profit from the investments by maximizing the use of the technologies to their full capacity and lifetime leading to (over-)committed emissions many years into the future (Erickson et al., 2015). Institutional carbon lock-in refers to an institutional context, wilfully created by a multitude of actors over a long period of time to support practices, markets, and organizations which benefit from the current exploitation of fossil resources and reinforces that pathway (Fuenfschilling and Truffer, 2014; Klitkou et al., 2015). Finally, behavioural carbon lock-in refers to values, norms, and routines in individual and collective behaviour which (unconsciously) relies upon and sustains carbon intensive goods, services, and forms of energy (Maréchal, 2010). The present research note aims to shed light on how one often neglected group of actors, large multinational corporations involved in plastics manufacturing, have intensified their efforts to bury our economies deeper in the carbon lock-in while deflecting their responsibility for the climate impact associated with the production of fossil-based plastics.

In the next section we dig into the structure of the carbon lock-in in plastics, presenting its origins and the contemporary pursuit of a continued and deepened lock-in by key actors. New empirical material is presented regarding the infrastructural and technological domain of carbon lock-in, showing how twelve of the largest MNCs in the sector used the last decade to invest in the expansion of fossil-based production. We connect this data to previous research to show how the wave of investments links to the other domains of lock-in that continue to be reinforced by industry lobbying activities and support for lifestyles consuming disposables as if there was no tomorrow – or at least no plastic waste to deal with tomorrow. We conclude with outlining a research agenda to improve the understanding of how this new frontier of carbon lock-in can be understood, as well as tackled through progressive energy, climate, and resource policy, which has to shift from its current focus on plastic waste management practices to directly address the rapidly growing supply of plastics.

2. Pursuing a deeper carbon lock-in in plastics

Following developments in petroleum engineering in the mid 20th century petrochemistry emerged as the future for the chemical industry, which previously had depended largely on coal-based chemicals. The demand for and production of petrochemical products grew rapidly in the postwar era with plastics being "the engine for growth" (Spitz, 1988) and the chemical industry becoming a cornerstone of growing western economies (Arora et al., 1998). Plastics denotes a large group of different polymeric materials, the production processes for which are different, but altogether[2] it constitutes by far the largest product category produced by the global petrochemical industry with a total production estimated to 420 million tonnes in 2017 (IEA, 2018). From 1950 to 1970 the annual growth rate in production of plastics was up to 20% and although demand growth has since decreased it has exceeded global GDP growth all years but two in the new millennium, averaging about 4% despite a drop after the financial crisis of 2008 (Geyer et al., 2017) and growing quicker than demand for any other bulk material (IEA, 2018). Plastics are omnipresent in contemporary economies, societies, everyday practices, as well as natural environments. Plastics are used extensively by the automotive, construction, electronics, and textile industries, thus constituting large parts of our cars, houses, computers, and clothes. We live in plastics, ride in plastics, work on plastics, and wear plastics – the materiality of plastics to a large degree define our lives (Gabrys et al., 2013). We further find plastics in our oceans (Eriksen et al., 2014; Worm et al., 2017), soils (Bläsing and Amelung, 2018; Chae and An, 2018), and even in the atmosphere (Allen et al., 2019; Brahney et al., 2020) where it is transported to even the most remote areas of the world (Bergmann et al., 2019). The notion of plastics as a new stratigraphic indicator (Zalasiewicz et al., 2016) shows that plastics are a major signifier of our epoch, which may thus be labelled the *plasticene* (Ross, 2018). Despite a growing recognition that the many ways we (mis)manage plastics and plastic waste have to stop (Rigamonti et al., 2014; Ryberg et al., 2019) the industry is counting on and pushing for a further growth of their current business model: using large volumes of fossil oil and gas to produce (mainly) short-lived products which are then discarded and either end up in natural environments, toxic land-fills, or combusted to add even more CO_2 to the atmosphere (Jambeck et al., 2015; Zheng and Suh, 2019). All the while our everyday routines continue to exacerbate what is now properly understood to be a *plastic crisis* (Nielsen et al., 2020).

2.1. Infrastructural and technological lock-in

The very material lock-in created by physical infrastructure and production technologies for plastics is a strikingly strong aspect of the carbon lock-in of the sector. Petrochemical production facilities require significant investments at the beginning but operate with relatively low running costs over their economic lifetimes – which are commonly several decades. It is estimated that two thirds of the cost of plastic production is the energy input – and as this energy is mainly derived from the same fossil resources that constitute the feedstock for the plastics, that makes the production highly carbon intensive – GHG emissions are between 2 and 5 kg CO_2eq per kg of plastic for the most common polymers (Zheng and Suh, 2019). The reinforcement of the intensive energy systems of these companies' industrial activities participate to postpone the development towards a low-carbon society. New investments in fossil based production capacity will proliferate the lock-in at least until the middle of the century when emissions should be approaching zero (Bataille, 2020). The past decade did see a major shift in the US petrochemical and plastics sector as large volumes of ethane were made available for plastics production through the deployment of fracking technologies for production of shale gas, which increased the available volumes of natural gas liquids (Sicotte, 2020). The situation with the market drowning in cheap ethane was exploited as an opportunity to increase and upgrade production, primarily in the US but with increasing export capacity for liquefied ethane this has spurred new investments also in Europe and Asia (Tullo, 2016a), instead of investing in alternative technologies and pathways (Amghizar et al., 2017). With decreasing production costs for chemical building blocks and plastics in many regions since 2010 (IEA, 2018) downstream markets have also benefitted. Indeed "growth is expected to be spurred by strength across major chemical end use markets and significant shale gas-linked investment on capacity expansion" (REUTERS, 2020).

The actors of the petrochemical industry can be defined as the corporate groups of firms with their value chain entirely dedicated to upstream resources extraction, transformation and downstream activities for transformation, transportation, and distribution for plastics and related products. It gathers multiples intertwined economic, financial, and logistical companies – many of the largest of which have direct connections to upstream oil and gas production and processing firms (Tullo, 2020). As there is sparse information and few datasets available on the activities in the sector, e.g. in international databases such as the UNIDO INDSTAT, we collected data on the investments made by twelve of the largest plastic manufacturing companies globally over the period 2012–2019. As data source we used information published in trade press, primarily *Plastics News*, which we cross-referenced with information made public by the firms, e.g. through news releases. More precisely, investments targeted the upgrade and increase of production

[2] The category plastics here includes thermoplastics (e.g. polyethylene and polypropylene), thermosets (e.g. polyurethane and epoxy resins), elastomers (e.g. nitrile and styrene-butadiene rubber), and synthetic fibres (e.g. polyester fibre).

capacity, the creation of new plants, the building of new research and development centres and we collected information about the type of investment, location, production capacity and product. The data shows how these actors are continuing to pursue a carbon lock-in by investing in technologies and infrastructures for fossil-based production, which will operate for decades, serving as an indication of the global development in the sector. The dataset does however not provide a complete picture as the source privileges Western and publicly listed companies which have strong incentives to announce their investments. The lack of information about investments in Asia does not capture the rapid growth of the Chinese industry over the period. However, the twelve firms selected are all key actors as they are among the largest firms globally in the industry as well as they have central positions in the tightly integrated network of organizations and elites that define the sector (Verbeek and Mah, 2020) and they thus serve as indicators of trends and development trajectories in the sector.

We identify 88 projects announced by the twelve companies we focused on, see Table 1. These projects are mainly investments in new or increased production capacities for monomers, polymers, and related facilities. 44 projects are located in North America, most of them located in the historical petrochemical clusters on the US Gulf Coast: Corpus Christi, Baytown, and Beaumont in Texas as well as New Orleans and Baton in Louisiana. These two US States have a high concentration of chemical industry clusters, due to their historical connection to the petroleum industry and strategic location for downstream infrastructures such as export and import terminals (Petak et al., 2017). Projects in Asia and Europe amount to 21 projects each, see Fig. 1. Capacity expansion in China is primarily driven by the proximity to Chinese manufacturing industry which has a seemingly insatiable demand for plastics. The recent investment wave has been especially focused on polyethylene production. 61 of the 88 projects we focused on were aiming for increasing ethylene and/or polyethylene capacities. A prime example of breaking new ground for carbon lock-in is the investment by BASF, the largest chemical company in the world, in a brand new petrochemical cluster in Guangdong, China, which, when completed in 2030, will be the largest investment in the history of BASF and the third largest cluster owned and operated by the company. That Ludwigshafen, where BASF established their first production facilities in 1866 remains their largest facility although the product range, feedstocks used, and downstream markets have changed is a tell-tale about the path dependency for these clusters.

As an end to the American expansion of shale gas production is foreseen – a development accelerated by the Covid-19 pandemic (Feit and Muffett, 2020) – the rest of the world is looking towards the future. That the industry sees the "future of oil is in chemicals" (Tullo, 2019) indicates that further infrastructural carbon lock-in remains on top of the agenda for these firms. Following the example set by ExxonMobil with their investment in a crude-based cracker in Singapore that opened in 2014, crude-based production of plastics and other chemicals is a priority for many actors around the world: from developers of oil refining and chemical technology such as Honeywell (Gugel, 2019), to integrated conglomerates such as Saudi Aramco and SABIC as well as focused chemical producers such as Zhejiang Petrochemicals who are investing in refinery technologies which maximize the production of chemical building blocks for plastics and other chemical products instead of fuels (Gupta and Xu, 2019).

Table 1
The studied companies and respective number of projects over the period 2012–2019.

COMPANY	IDENTIFIED PROJECTS
Borealis	10
Braskem	4
Chevron Phillips	2
Dow Chemical	11
Exxonmobile	9
Formosa	5
Ineos	12
LyondellBasell	12
Reliance	2
SABIC	12
Sinopec	4
Total	5
TOTAL	88

The high pace of capital intensive investments supports infrastructures that will last for decades. In a sense the infrastructural and technological lock-in is a burden that will increase path dependence in reproducing fossil fuel-based model to the next generations. Recent investments are likely to have crowded out low carbon options from the project portfolio of these firms despite their significant responsibilities for greenhouse gas emissions, other environmental impacts and capability to implement new industrial norms and long term behaviours.

2.2. *Institutional lock-in*

Apart from investing billions of dollars into new infrastructure and technology that will reinforce the carbon lock-in for decades to come the plastic industry is also working to maintain and fortify institutional structures that support the same lock-in. As plastics have become increasingly politicized – particularly as an effect of the growing recognition of the need to manage its contribution to marine pollution through both domestic policy and international agreements (Dauvergne, 2018) – the industry has maintained that the production and use of plastics is unproblematic and that the pollution problem is purely an issue of mismanaged waste (Mah, 2021). This deflects attention away from efforts of rethinking how materials are used and whether a production that grows in all directions contributes to societal value, and puts the responsibility purely at end consumers and waste management systems. However, plastic pellets (or nurdles), the form that plastics take at primary production have been identified as a common plastic pollutant in many locations (Barnes et al., 2009). Although the presence of some of these pellets are due to accidents when transporting or shipping plastics significant volumes have been identified as originating directly from plastic production sites (Karlsson et al., 2018). Despite the fact that institutional structures are in place to protect natural environments from industrial pollution these rarely explicitly target this type of pollutant (ibid.), and when they do the regulation is so lax that it allows for unabated continued pollution (Lechner and Ramler, 2015). The increasing production of plastics which will be the result of the investments reported in the previous section is thus likely to exacerbate this problem too, unless plastic manufacturers accept their responsibility also in this domain – which could likely be mitigated much easier than the fossil dependency.

Regulations on plastics have however been introduced over the past 20 years. An institutional homology has been established in which regulations target specific types of plastic products, primarily plastic bags which are now banned or otherwise regulated by cities, regions, and countries on all continents around the world (Nielsen et al., 2019). Afraid that this would be a tipping point leading to stricter regulations against plastics in more domains the industry in the US has pushed back with lobbying and legal countermeasures (Romer and Foley, 2012). This led to several US states adopting *bans against bans* on plastic bags (Nielsen et al., 2019), ensuring a continued favourable institutional structure for the industry. Although bags are just a small part of the market for plastics, they have become powerful symbols in the cultural and institutional battle on the future of plastics. This battle is being fought in legislatures as well as courts as the industry has opposed the restrictions implemented (Wang et al., 2019). Another such symbol has been plastic water bottles, around which there have also been conflicts. Cities, which have to manage the problem of plastic bottles ending up in parks, on beaches, and at playgrounds, have attempted to set local restrictions to limit their use and support alternatives. These attempts for institutional solutions which would reduce the use of plastics have

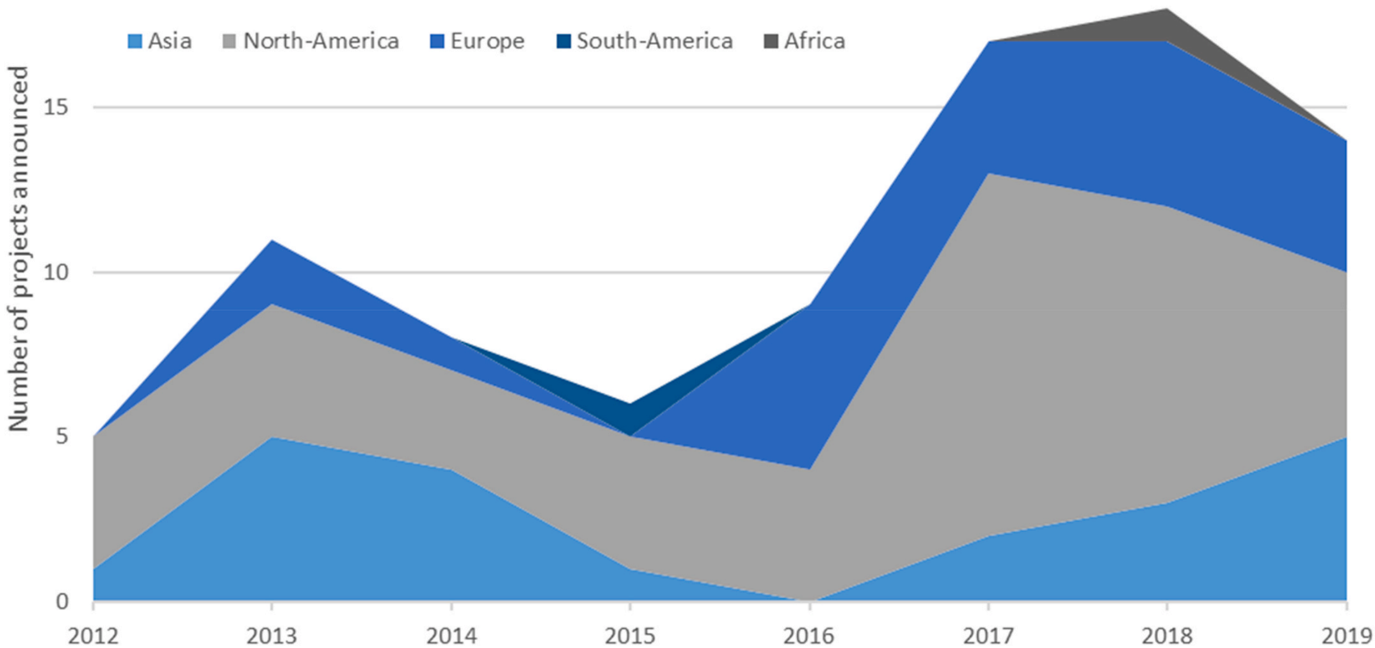

Fig. 1. Identified projects announced over the period 2012–2029 b y continent.

repeatedly been opposed with significant local engagement by plastic industry actors and even litigation, while instead supporting solutions such as putting out more trash bins (Clapp, 2012) – doing nothing to reduce the total volume of plastic used for bottles, but instead ensuring that demand keeps up with increasing production capacity.

The EU signalled in its first action plan for a circular economy of 2015 that plastics was a prioritized area and that it would develop a strategy on plastics to address "issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter" (European Commission, 2015). The roadmap presenting the details of the plan for the plastic strategy specifically included the high dependence on virgin fossil feedstock as one of the three problem that the initiative would tackle, but during processes of stakeholder consultation this became delegitimized and marginalized (Palm et al., 2021). In the end the final strategy, which aims to transform the plastics economy, thus does not explicitly address the proliferating carbon lock-in, but hopes for more recycling as the main solution to most problems associated with plastics. Simultaneously industry consultants are guiding the plastic industry through reports which are promoted with the million dollar question "how can a circular plastics economy grow the oil industry?" confident that developing a circular economy will take so much time that it will have "minimal impact on chemical demand growth due to rising incomes, populations and living standards" as phrased by the influential consultancy firm Wood Mackenzie (Wood Mackenzie, 2018). While formally acknowledging the necessity of a circular economy, the industry is forming alliances to contain the threat a proper circular economy would pose to institutionalized practices, business models, and resource use (Mah, 2021). So far this is seemingly successful as circular economy policy packages to a significant degree have been patched onto existing insitutions and regulations rather than challenging and substituting them (Fitch-Roy et al., 2020) and do not fundamentally rethink the role of consumers (Hobson, 2021).

2.3. Behavioural lock-in

The contemporary understanding of plastics can be summarized in one word: disposable. In the early days of the industry this was however not the case as plastics were valuable materials, used for products and applications which acknowledged a key material property of plastics: they last forever. Reaching this state of omnipresence required significant efforts of the industry. In addition, the insidious expansion of "mundane plastic packaging" has deeply colonised contemporary behaviours and cultures. The convenience of these versatile thermoplastic materials, synonymous with comfort and modernity hides political implications. The multiple functions and values of this material has benefited from its incremental normalisation and use, implementing its necessity in governing the mindset and practices of the entire value chain for the food production. It stimulated irrational marketing campaigns by shifting gradually landmarks for consumer habits over time (Hawkins, 2018). Demand for all plastic products that we surround us with today was never there to be met, rather demand was invented and taught to consumers following the discovery of new and interesting properties in the polymer lab (Meikle, 1995). The cheap and abundant source of feedstock for plastics made it a perfect fit for the emerging consumer culture which took decades to institutionalize in western economies in the post-war era (Strasser, 1999). The creation of the notion of large volumes of waste being part of everyday life led up to a situation in which plastics were disposable, implying a never saturated market for plastic products. Plastics were connoted with ideas of modernity and convenience to create the idea of "throwaway living" in the 1950s (Parker, 2018). This was saluted by the plastic packaging industry as a milestone 60 years ago: "The happy day has arrived when nobody any longer considers the plastics package too good to throw away" (Stouffer, 1963). Ever since, the efforts have increased to create and support habits and behaviour leading to a constantly growing use of disposable plastic goods. Naturally, this development has not been uniform around the globe but is a hallmark of wealthier countries - while the global average annual per capita demand for plastics is 45 kg it is about three times larger in NAFTA and Western Europe but only a third in Africa and the Middle East (Plastics Insight, 2016).

When in recent years this development for the first time has been threatened by policy the industry has resisted. As one should never let a crisis go to waste the plastic industry used the covid-19 pandemic – which has led to collapsing markets for commodity plastics – to lobby against the use of reusables and for rolling back legislation on single-use plastics and plastic bags, just as consumers were beginning to adjust their behaviour (Schlegel and Gibson, 2020; Simon, 2020; Toloken, 2020). The recent investments in increasing production capacity in the US and EU presented above may be particularly sensitive to this development as they to a large degree are focused on polyethylene, the simplest and cheapest of commodity plastics and thus the primary one used for low-cost single-use items. Ensuring that policy and behavioural change does not restrict the markets for these products will thus be key for the profitability of recently made investments in production.

Naturally, if there is a never-ending flow of single-use or other short-lived plastic products, there is a never-ending flow of plastic waste to be managed (Liboiron, 2013). Since the 1970s the plastics industry has supported plastic recycling and promoted the responsibility of individual consumers to ensure that plastic waste is collected for recycling (Buranyi, 2018) despite the fact that only 8% of all plastics have actually been properly recycled (Geyer et al., 2017). Although it is well known that plastic packaging to a large degree is in fact non-recyclable (Tullo, 2016b) the main responsibility is put on consumers to ensure that they recycle their packaging waste properly to reach policy goals for recycling. For decades the plastic manufacturers and their trade associations invested in campaigns to get consumers to adopt a behaviour focused on enabling recycling of plastics while knowing that the material would in fact not be recycled (Sullivan, 2020). Following the adoption of new waste collection strategies which increased the available volumes of plastic waste the exports of waste plastic increased rapidly around the turn of the millennium (Brooks et al., 2018). However, waste plastics were mainly exported from Western economies, the origin of the largest plastic firms and the consumers of the plastics primarily to China, which is also the country with the largest volumes of mismanaged plastic waste (Jambeck et al., 2015). China has in the past few years started regulating imports of recyclates very strictly, showcasing the connection between behavioural and institutional lock-ins. Exports then instead shifted primarily to other countries in South-East Asia, e.g. Malaysia, Vietnam, and Thailand (Hook and Reed, 2018) - which are also among the top countries for mismanaged plastic waste. As there is still a deficit for recycling capacity in most Western countries exports have continued, with the illegal trafficking of plastic waste growing rapidly (INTERPOL, 2020). Also stricter international regulation of plastic waste trade is being opposed with significant lobbying efforts (Tabuchi et al., 2020).

Meanwhile, industry efforts are focused on completely different strategies than designing for recycling or reuse (Van Sluisveld and Worrell, 2013). Regarding other types of plastic waste than packaging recycling is even worse. Despite regulations being in place on waste electric and electronic equipment (WEEE) and end-of-life vehicles, and consumers behaving in line with regulations, WEEE and automotive plastics are not recycled as they are manufactured in ways that prohibit recycling (Buekens and Yang, 2014; Buekens and Zhou, 2014). If they are recycled they still risk carrying dangerous and many times prohibited toxins into new products (Leslie et al., 2016). A continued focus on individual behaviour of end consumers instead of change in the way plastics are manufactured and compounded, plastic products are assembled, and plastic waste is traded thus continues to exacerbate the dependence on virgin fossil plastics.

3. Conclusions and policy implications

In this research note we have outlined the nature of the carbon lock-in of the plastics industry, and shown how key actors in the industry are actively – against the promises of the Paris Agreement – pursuing a continued and deeper entrenchment into fossil resource use and dependency. Across the domains of technologies and infrastructure, institutions, and behaviour key actors in the industry – the plastic dinosaurs – are continuing their efforts to expand markets for plastics based on oil and gas. A wave of investments in new and increased production capacity for many kinds of plastics has swept over the world – originating in North America as the continent was flooded with low-cost shale gas and then spilling over both the Atlantic and Pacific oceans. A new wave is approaching, but this time focused on maximizing the conversion of crude oil to chemicals. It is crucial to understand how the current lock-in has been wilfully created and continues to be actively reinforced by key actors. The next step is to identify policy reforms and governance initiatives which can break the connections between the domains of carbon lock-in and show that alternative development paths are possible. Systemic policy beyond fees and restrictions on individual product categories such as plastic bags and single-use items will also be needed. Such a systemic policy must acknowledge the truly transformative potential of a circular economy approach and not diminish it to simple additions to existing frameworks, thus considering challenges to supply dynamics and our wasteful use of plastics as well as limitations to the currently unhindered demand growth.

Climate and energy policy and research has hitherto remained surprisingly reluctant to engage with this sector and the implications of its projected growth. Ensuring access to better data and information is a priority for both researchers and policymakers moving forward. Internationally comparable statistics about production and investments in the sector – as supposedly collected through UNIDO – is required. Future research should also investigate the direct as well as indirect connections to and pressures from the oil and gas industry on the plastics industry. Research should also aim to identify ways of breaking up the special connection between these sectors that has endured for a very long time. Moreover, there is a great need for knowledge on how the sector benefits from public subsidies – both those directly aimed at the sector as well as those indirectly benefitting its activities by subsidising exploration and exploitation of oil and gas resources. Finally, it is also important to investigate how and to what degree different pathways for breaking the carbon lock-in, such as circular economy approaches or bio-based plastics, really challenge the existing industry logics and structures as well as what risks there are for initiatives along these pathways to become isolated and used for greenwashing. Mitigating these knowledge gaps will be crucial to enable more effective policy reforms and governance initiatives.

As different forecasts and analyses have shown, future earnings for oil and gas are increasingly to be found in plastics and other petrochemicals as these markets are growing with increasing global affluence. Whereas policies have been implemented in many countries to support a transition away from using petrol and diesel in transportation and towards investing in renewable electricity generation, this downstream market has been largely neglected and must be a part of future strategies for phasing out fossil fuel dependence. Extending the scope of plastic policies from the collection of plastic waste and reducing the demand for single-use products is imperative. Although plastics production is likely to continue to grow globally, institutions must urgently be put in place to challenge the fossil logics that dominate the industry. More attention must be paid to curbing the growth in demand for virgin fossil feedstocks in the sector and explicitly connect this to improving and increasing recycling. While the increasing calls for a circular economy in some ways do this, it is clear that these are still by no means backed up by comprehensive policies and instruments that challenge the logics and expansion plans of the industry. Restricting the use of virgin fossil resources in new plants and effectively including the industry in carbon tax or emission trade schemes could be first steps. As the value chains of the industry are global, international cooperation on the topic is an absolute necessity and must be protected from corporate capture. Policy must also confront the false promises of recycling that have shaped consumer behaviour and perception for decades, implementing stricter requirements for recyclability of plastic products in key end-use markets, creating demand for recycled plastic materials at the expense of virgin plastics, and ensuring an increase in effective recycling capacity. Although there are new governance initiatives in different geographies aiming for some of these later issues, they still seemingly address one product category at the time in a patchwork-like manner and are far from the comprehensive and systemic response the issue calls for.

CRediT authorship contribution statement

Fredric Bauer: Conceptualization, Writing – original draft, Writing – review & editing. **Germain Fontenit:** Investigation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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