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Research article

Of booms, busts, and sustainability: A socio-technical transition study of Iceland's mobility regime and its proximity to strong sustainability

Kevin Joseph Dillman [a,*], Jukka Heinonen [b], Brynhildur Davíðsdóttir [a]

[a] *Environment and Natural Resources, School of Engineering and Natural Sciences, University of Iceland, 107 Reykjavík, Iceland*
[b] *Faculty of Civil and Environmental Engineering, School of Engineering and Natural Sciences, University of Iceland, 107 Reykjavík, Iceland*

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A B S T R A C T

The need to reconfigure provisioning systems to achieve a good life within the planetary boundaries has been recognized, but few studies have investigated the temporal change dynamics of such systems in the context of strong sustainability. Using Iceland's mobility sector as a case study, the effects of significant economic swings and other landscape/innovation developments from 1995 to 2018 were narrated. The influence of these factors on Iceland's mobility provisioning, and the associated impact of these changes on the sector's ecological overshoot and transport poverty/social externality indicators, were considered. The results showed that Iceland came close to achieving a just space by the end of the period, but where significant overshoot was seen throughout. This overshoot fluctuated with the country's economic booms and busts, reaching almost 1.5x at its peak as compared to its lowest point. These results identify the need to reduce the ecological intensity of Iceland's mobility provisioning.

1. Introduction

The past thirty years of socioeconomic history could be characterized as a time of increased global prosperity and improved well-being, where one billion people escaped extreme poverty (The World Bank, 2022b). Beneath the surface of these cheery headlines, however, economic booms and busts and a series of recent systemic shocks have disrupted the lives of billions (The World Bank, 2022b; Hickel, 2016). Throughout these crises, the top global 1% managed to appropriate 38% of all additional wealth accumulated, while the bottom 50% only received 2% of this wealth (Chancel et al., 2022). This inequity occurred while the continued exponential growth in human activity and consumption has led to the simultaneous growth in environmental pressures, bringing humanity to the cusp of ecological crisis (Steffen et al., 2015).

While the current political economy continues to promote GDP growth-orientated development as the key to increased well-being, there are those who recognize this paradigm as unsustainable (e.g. Raworth, 2017; Wiedmann et al., 2020; Hickel and Kallis, 2020; Hickel et al., 2021, 2022). Researchers have presented alternative 'strong sustainability' approaches that promote well-being, rely on eudemonic, needs-based, and sufficiency-orientated well-being perspectives to develop 'just' social minima and the necessity for these needs to be met within 'safe' ecological maxima, such as the planetary boundaries (Raworth, 2017; Fuchs et al., 2021; Lamb and Steinberger, 2017).

* Corresponding author.
E-mail address: kjdillman@hi.is (K.J. Dillman).

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In an assessment of the ecologically 'safe' and socially 'just' global performance of nations, however, no country was found to be meeting all its citizens' needs within the planetary boundaries (O'Neill et al., 2018). Expanding this work temporally, Fanning et al. (2022) studied the same indicators as O'Neill et al. (2018) across 140 countries from 1992 to 2015 and found ecological transgression was occurring at a faster pace than social thresholds achieved. Fanning et al. (2022) and other scientists (e.g. Haberl et al., 2020; Haberl et al., 2019; Hickel et al., 2018) have suggested that this could be linked to socio-ecological inefficiency of provisioning systems (e.g. food, healthcare, and mobility systems, etc.), where nations have not been able to meet the needs of their citizens within the planetary boundaries. Studies have investigated the socio-ecological performance of nations, but these studies have nearly always only considered the connection between ecological impacts and higher-order indicators such as life expectancy (Dietz et al., 2012; Knight and Rosa 2011; Lamb et al., 2014; Vogel et al., 2021). Lacking from the literature, however, are system-level temporal perspectives of how the socio-ecological efficiencies of provisioning systems change over time.

We attempt to accomplish this by studying the socio-ecological performance of mobility systems over time, where mobility represents an essential provisioning system in modern society (Mattioli et al., 2020) and where the need to tie historical and socio-metabolic perspectives has been identified in transition literature (Groß et al., 2022). While mobility itself may not be considered a basic need, it acts as a non-substitutable prerequisite to access essential services, employment opportunities, and connect with society (Mattioli, 2016). It has increasingly been seen as a critical intermediate need and incorporated into basic service/need frameworks (e.g. Rao and Min, 2018; Büchs, 2021; Coote, 2021). Not satisfying basic mobility needs has been recognized for the harm they can cause in the form of transport poverty (Lucas et al., 2016), aligned with sufficiency (Lamb and Steinberger, 2017) and minimum consumption notions of justice (Heyen, 2022). Mobility systems cause further suffering in the form of significant social externalities. Traffic fatalities are the leading cause of death globally for those between 5 and 29 years of age (WHO, 2022). Air and noise pollution associated with transport activity can further cause significant health impacts (WHO, 2018, 2021; Apte et al., 2012). Environmentally, as global mobility activity continued to rise, ground mobility systems were accountable for 10.7% of global GHG emissions in 2018, where increased demand has outpaced environmental efficiency gains, and developing countries are increasingly motorizing (Lamb et al. 2021). Mobility infrastructure and vehicles additionally come with significant materials and embedded emissions (Hertwich, 2021; Vírag et al., 2022; Lettenmeier et al., 2014). Many studies have investigated the sustainability of transport systems, but they have almost always been unrelated to the thresholds and thus cannot determine when the defined intergenerationally sustainable state has been achieved (Dillman et al., 2021; Holden et al., 2013).

Transitioning mobility systems has been a notoriously challenging task, as they represent a highly locked-in sector with complex infrastructures, institutions, and vested interests, which can lead to high path dependency, making them resistant to change (Næss and Vogel, 2012; Driscoll, 2014; Mattioli et al., 2020). With the growing recognition of the importance of a just transition and one that should not be overlooked in efforts for a green transition (Sherriff et al., 2022), an integrated approach which investigates the temporal developments of both social and ecological performance over time is needed, and answers calls in the literature to do so (Jenkins et al., 2018; Köhler et al., 2019).

This study, therefore, conducted a longitudinal case study of Iceland's mobility provisioning from 1995 to 2018, utilizing the Multi-level Perspective to map landscape, regime, and innovation developments. The aim was to investigate how these changes influenced the strong sustainability performance of Iceland's mobility sector.

Iceland serves as a case study worthy of international interest due to the acute economic volatility seen during the study period and the influence of these developments on the transport sector. Since the 1990s, the country saw significant economic booms and busts, most famously during the banking crisis, which pushed Iceland into the deepest recession seen in any developed country within the past 50 years (Johnsen, 2014), after which the country bounced back to become one of the most affluent countries in the world per capita (The World Bank, 2022). This economic volatility provides a graphic example of international interest due to the associated rapid changes to mobility stocks and activity, allowing for an investigation into the environmental and social impacts (Ulfarsson et al., 2015). Further, with the car-orientated, sprawled urban form experienced by most of the country's population (Collin-Lange, 2014), and a prevailing strong car-orientated mindset (Heinonen et al., 2021), Iceland can act as an international example of the challenges in achieving mobility-related social foundations within the planetary boundaries under such a configuration. Particularly with the country having some of the highest rates of EV penetration globally, this makes the conversations regarding the co-benefits of an EV-centric route timely and relevant to the case study, whereas, in other countries, EV markets are still in their early stages (IEA, 2022). Lastly, the country's capital, Reykjavik, has consistently accounted for approximately two-thirds of the country's population from 1995 to 2018 (Statistics Iceland, 2022b). With the country's small relative size and homogenous populations, this allows studying the urbanizing effects of Reykjavik and the city's development to act as a good proxy for the rest of the country, which would be significantly more difficult in a country with a dispersed population and diverse urban forms. It is worth noting that Iceland can often be considered a geographic, demographic, and economic outlier due to its relatively small, geographically isolated population with high GDP per capita relative to other nations. We address these limitations in Section 3.3 in the Methods and Materials section.

This work makes a set of academic contributions. First, this case study provides both an explicative narrative and an empirical study of the socio-ecological performance of a provisioning system, answering calls in the literature for such investigations (Hickel et al., 2022; O'Neill et al., 2018). Second, while other studies have looked at transport poverty (Upham et al., 2022) and transitions in the mobility sector in Iceland (Lin and Sovacool, 2020; Shafiei et al., 2017; 2018; 2019) and elsewhere (e.g. Geels, 2018; Hillman and Sandén, 2008), no study has bridged these fields in Iceland or in another Nordic welfare economy. Quantitatively studying (transport) justice over time through a socio-technical lens marks a contribution to a significant research gap (Jenkins et al., 2018; Köhler et al., 2019). Third, this work adds to the socio-technical literature by providing an interesting and illustrative case study of rapidly changing consumption behaviour and socio-technical system development under volatile conditions and times of change/innovation (e.g. EVs, tourism boom) (Duffy et al., 2017; Keeling, 2020). Such volatility could potentially aid in interpreting beneficial/detrimental relationships between macroeconomic developments and provisioning/ecological impacts (Geels, 2018).

This paper is organized as follows. First, the analytical framework we employed to answer the research question, where we conceptually bridge socio-technical transition and provisioning system theory, is described. The defined 'safe' and 'just' space for Icelandic mobility was then described, with supporting information provided in the Appendix. The results narrate a socio-technical review of developments in Iceland's mobility provisioning system and connect them to its strong sustainability performance. The discussion provides a discourse on the influence of developments, on multiple levels, which influenced mobility stocks and activities which in turn influenced sustainability performance. The importance of connecting socio-technical study methods and strong sustainability concepts was then discussed, with the final section concluding.

2. Analytical framework

In this section, we provide a theoretical background for provisioning system/ecological economic and Multi-level Perspective (MLP) concepts, discussing their limitations. We then argue for bridging these concepts and explain the application of this bridged framework in our work. The Methods and Materials section details the case study and data used to employ this framework.

2.1. Overview of provisioning systems

Provisioning systems, as defined by Fanning et al. (2020), transform resources to meet human needs and capabilities, converting resources like minerals and fossil fuels into material stocks such as roads and vehicles. The demand for these services results in a social metabolism for the system (Schaffartzik et al., 2021). In the case of mobility, transport and accessibility serve as the means to satisfy basic needs like physical health and social participation, as described in the Introduction and elucidated by Mattioli (2016). The required transport activity to satisfy these needs (and wants), outside of active transport modes with limited reach, requires energy, which to date has been heavily fossil fuel dependant (Lamb et al., 2021). The growth of these activities and supporting infrastructures in turn lead to both environmental (e.g. GHG emissions, land use change) and social externalities (e.g. air pollution, traffic injuries, noise, etc.) (Dillman et al., 2022). The socio-ecological efficiency of these systems can be described according to their ecological intensity of well-being, i.e. how efficiently they convert ecological resources (and outputs) into well-being outcomes.

As illustrated in Dillman et al. (2023), the provisioning system framework lends itself to other ecological economics concepts such as Sustainable Consumption Corridors (Fuchs et al., 2021) or Doughnut Economy perspectives (Raworth, 2017), where the system inputs and outputs can be tied to ecological maxima tied to planetary boundaries or other ecological limits (Röckstrom et al., 2009) and social minima connected eudemonic or other such attempts to measure objective well-being (Lamb and Steinberger, 2017; Wiedmann et al., 2020). The strength of such frameworks is the ability to define sustainable system states as opposed to solely relative sustainability directions (Holden et al., 2013; Dillman et al., 2021).

The shortcoming of these frameworks, however, is that while they perhaps implicitly consider change dynamics, they are less explicit in discussing system change and reconfiguration over time, where this temporal aspect is of key interest in our study. Second, while they are effective in capturing strong sustainability states and socio-ecological outcomes, they do not implicitly address exogenous landscape and innovation changes which can potentially influence these socio-ecological outcomes. Particularly since moving these systems towards a sustainable state will necessitate substantial reconfiguration (changes to policy, practices, states, and techniques, as well as their connections to other provisioning systems), prominent scholars have identified the need for research that would foster a more profound comprehension of how provisioning systems can reconfigure to improve socio-ecological efficiencies (Fanning et al., 2020; Hickel et al., 2022).

2.2. Overview of the multi-level perspective

To address these shortcomings, we introduce socio-technical transition theory, particularly the multi-level perspective (MLP) to study change dynamics and socio-ecological system performance over time (Geels and Schot, 2007). A common method employed to study such change dynamics within the transition literature, which this paper will focus on, is the multi-level perspective (MLP) (Markard et al., 2012). The MLP integrates findings from various literatures to analyse the complex dynamics of socio-technical change, encompassing three levels: niches, socio-technical regimes, and the socio-technical landscape. The strength of this approach is that this allows for the examination of the interactions amongst niches, socio-technical regimes, and landscapes, and aids in identifying windows of opportunity for radical innovations, understanding the barriers to their success, and designing targeted interventions for fostering technological transitions that lead to more sustainable and efficient systems (Geels and Schot, 2007; Markard et al., 2012).

Yet, two limitations in the transition literature exist that we address here. The first is that transition studies often focus on 'green' transitions but almost entirely rely on the assumption that the studied transition will lead to lower environmental pressures while failing to measure the scale of change in environmental pressures or social impacts and proximity of the changed system to a strong sustainability state (Geels et al., 2015; Feola, 2020). Second, socio-technical transition studies often struggle to consider "socio-economic problems as such poverty, inequality, problems in democratic accountability, happiness" associated with the transition under study (Geels et al., 2015; Geels, 2019). This can lead to challenges for example when determining which technology to prioritize to promote a sustainability transition, or which transitions could be considered 'more' sustainable due to the lack of clarity in terms of defined sustainable states and the ability to benchmark to them (Susur and Karakaya, 2022).

2.3. Conceptually bridging the two frameworks

In an effort to address these limitations, this study aims to integrate ecological economic concepts, such as provisioning systems and sustainable consumption corridors, with the Multi-Level Perspective (MLP) framework. By explicitly examining the evolving dynamics of regimes (which we equate to provisioning systems) over time, we can consider factors such as changing user behaviour, mobility culture, technological advancements, business innovations, and policy conditions. Analysing regime developments using diverse qualitative and quantitative sources enables the construction of data-driven narratives that trace the transformations of the regime in question over time.

Positioning the regime as a provisioning system and connecting it to a contextually developed Sustainable Consumption Corridor (SCC) allows for the visualization of both ecological impacts and social outcomes throughout time. These measurements can be then used to assess socio-ecological efficiency. Combining these results, a bridged approach such as we suggest can a) provide the context for understanding *why* socio-ecological performance changed and b) measure how landscape, regime, and innovation changes in the system led to various socio-ecological outcomes, more than either approach thus far has been able to do individually. Furthermore, grounding the MLP in strong sustainability contexts can aid researchers in moving beyond the capitalist paradigm of unbridled capital and economic growth, which often underpins transition studies (Antal and van den Bergh, 2014; Gillingham et al., 2016; Feola, 2020). This approach mitigates the boundary problem often encountered in socio-technical transition studies. By adopting a life cycle perspective and integrating social and environmental issues, we propose a method for more objective boundary setting and benchmarking when comparing transitions. While not a panacea, this represents a step forward (Susur and Karakaya, 2022).

Finally, we operationalized this bridged framework by performing a socio-technical review of Iceland's mobility system (1995–2018) and mapped developments in an adapted MLP framework, visualizing all the mentioned dynamics at the end of the review for interpretative purposes (Fig. 5). After describing the contextually developed SCC, we measured the socio-ecological efficiency of Iceland's mobility provisioning. The MLP narrative, with its focus on change dynamics and evolving contexts, enriched the strong sustainability approach by providing insights into how different factors interact and influence socio-ecological outcomes. Conversely, the strong sustainability approach enhances the MLP by embedding it in a framework that quantitatively evaluates ecological impacts and social outcomes, enabling a more comprehensive assessment of system performance. By examining both the narrative of how provisioning has evolved and the quantitative assessment of strong sustainability, we could more effectively interpret the impact of these changes and identify potential pathways, and supportive transitions, to achieve a safe and just system state.

3. Methods and materials

3.1. Socio-technical review

Placing our framework in the context of the study, with the research goal of studying the temporal change dynamics of Iceland's mobility provisioning and the strong sustainability outcomes associated with these changes, we first performed a socio-technical review of Iceland's mobility provisioning. This review studied academic papers, policy documents, textbooks, and books to develop timelines of system-level developments, and collected empirical data on changes to key indicators (such as vehicle stocks, GDP, road infrastructure investment, etc.) over the study period (1995–2018). At the end of the review, we coalesced our findings into a temporal depiction within our adapted MLP framework in an attempt to illustrate the relationships between various landscape, regime, and innovation level developments, similar to previous studies (e.g. Gingrich and Krausmann, 2018; Geels, 2018). The next sub-section then describes how strong sustainability performance was assessed.

While national developments are the focus, Reykjavik will often be the point of focus regarding urban development, due to its

Table 1
Threshold and performance indicators, threshold value, and indicator source for the ecological ceilings and social foundations used in this study.

EC/SF	Threshold/Performance Indicator	Threshold value (unit)	Description	Indicator source
EC1	*Household transport consumption based GHG emissions*	0.81 $tCO_2eq.\ cap^{-1}\ y^{-1}$	Akenji et al. (2021) for the 2030 threshold and Clarke et al. (2017) for Iceland's consumption-based footprint composition	OECD, Statistics Iceland
EC2	*Material Use*	0.75 tonnes of material consumption $cap^{-1}\ y^{-1}$	Lettenmeier et al. (2014); Ivanova et al. (2016)	OECD, Statistics Iceland
SF1	*Accessibility*	8,000pkm $cap^{-1}\ y^{-1}$ AND 400,000 ISK income $cap^{-1}\ month^{-1}$	Derived from survey to develop contextual value (Heinonen et al., 2022)	OECD, Statistics Iceland
SF2	*Affordability*	20%	Derived as average of thresholds suggested by previous studies (10–25%).	Statistics Iceland
SF3	*Traffic Fatalities*	1.73 fatalities per 100,000 people	Derived from UN SDGs (2015) using Iceland's 2015 5-year moving average of 3.47 fatalities per 100,000 people	OECD, Statistics Iceland
SF4	*Noise Pollution*	5.7%	Derived using similar method as for SF3. In 2015, 11.4% of the population reported as having been bothered by noise.	Statistics Iceland
SF5	*Air pollution*	5 $\mu g\ m^{-3}\ cap^{-1}\ y^{-1}$	World Health Organization (2021)	OECD

proportional importance and documented history in the Icelandic context. Throughout the study period, the capital area accounted for 60–64% of the country's population, allowing Reykjavik to act as a good proxy for developments in the other urban areas of Iceland (Statistics Iceland, 2022a). Lastly, it is recognized that the space available here is, of course, not sufficient to capture the full nuance or passing of all events relevant to Iceland's mobility sector, but rather this work seeks to characterize the study period to build the temporal study context needed to interpret changes in the system's sustainability performance.

3.2. Socio-ecological indicators

For the sake of brevity, we shortly describe the socio-ecological indicators used in the study here, derived from previous studies (Dillman et al., 2021; Dillman et al., 2023), which are shown in Table 1. For expanded descriptions, we guide readers to the appendix. In the Appendix, we describe in greater detail how the thresholds and indicators were selected and measured, as well as the multi-criteria decision analysis (MCDA) approach we took to weight the indicators. We followed an expert-driven survey approach to develop a contextually relevant sustainable consumption corridor (SCC), which defines this work's safe and just space for mobility, following approaches suggested in the literature for SCC development (Dillman et al., 2021; Fuchs et al., 2021) and sustainability index studies (e.g. Waas et al., 2014).

For the ecological ceilings, GHG emissions and material use were the indicators selected. For GHG emissions, a per capita threshold based on previous research was used as the threshold for limiting global warming to 1.5 °C (Akenji et al. 2022), which was found to be aligned with the IPCC's AR6 report (Heinonen et al., 2022). A consumption-based approach, allocated to households incorporating the direct and indirect emissions from transport, was taken in this work to integrate the impact of consumption behaviour and provisioning. For material use, per capita material use thresholds were taken from Lettenmeier et al. (2014). These two indicators were chosen for ecological ceilings as two of the most relevant environmental impacts of ground transport (Ivanova et al., 2016), as well as due to the measurability and data accessibility criteria required when selecting indicators (Sdoukopoulos et al., 2019). It is important to note that these are both per capita indicators, and thus changes in them don't necessarily reflect changes in absolute impacts.

To measure social achievement, we used five social indicators derived from previous works studying minimum consumption, transport poverty, and mobility externalities (Lucas et al., 2016; Mattioli et al., 2017; Dillman et al., 2021; Dillman et al., 2023; Gupta et al., 2022), which followed previous 'safe' and 'just' assessments (e.g. O'Neill et al., 2018; Raworth, 2017) and other social justice frameworks (Rammelt et al., 2022). This selection included two needs satisfaction indicators (accessibility, affordability) and three social externalities indicators (traffic fatalities, noise pollution, air pollution). For each indicator, we state the value estimated to be representative of the minimum requirement to live a 'good' life in Iceland. We recognize the limitations and potential subjectivity of these values in the Discussion but strived for these to be as objective as possible through the use of eudemonic well-being frameworks (Lamb and Steinberger, 2017).

3.3. Limitations

Before moving into the results, we wanted to first recognize some limitations to our approach. First, regarding the socio-technical review, due to the interest in bridging this field and socio-ecological performance, and the need to capture both landscape and regime-level development, the review was necessarily brief. Second, while Icelandic policy documents are increasingly being translated into English, many historical documents can only be found in Icelandic, and while the research team had some Icelandic knowledge, this inherently makes search protocols more difficult.

For the socio-ecological performance, significant data limitations exist in Iceland regarding modal share, accessibility to public transit, and other environmental footprint data such as ecological footprints, therefore necessitating the omission of some of these indicators or the use of proxy indicators (e.g. the use of total mobility to measure accessibility). For the indicators used to measure socio-ecological performance, a couple of points are worth mentioning. First, while the ecological thresholds were presented as static absolute targets (i.e. the GHG threshold being a 2030 target for GHG emissions), where this is necessary for developing a consistent benchmark, in reality, these thresholds are dynamic targets. Thus, though presented here as static, readers should recognize the closing window of the ecological overshoot targets (particularly for GHG emissions) (Guinée et al., 2022). Second, the social indicators were established with the goal of contextual relevance, where the setting of an appropriate amount of transport needed to have sufficient accessibility (Rammelt et al., 2022; Millward-Hopkins et al., 2020; Holden et al., 2013), or appropriate spend on transport (Litman, 2021) are inherently subjective and context-specific, though the selection was based on objective needs-satisfaction approaches. Additionally, due to the challenges associated with establishing eudiamonic thresholds for aviation mobility consumption, we selected our scope to only consider ground mobility, but aviation is an increasingly important driver of mobility-related environmental impact, both for Icelanders and globally (Czepkiewicz et al., 2018, 2019), and the limitations of only considering ground mobility requires recognition.

Lastly, the generalization potential of Iceland needs to be put into context. Iceland is a country isolated geographically with a relatively small population with an economy that is not highly diversified with an independent small currency. Thus, the banking crisis was able to have an outsized impact as well as more easily take on financial risks many times the size of the country's GDP (Johnsen, 2014). The country's small independent currency subject to inflation and exchange rate volatility heightens the Icelandic economy's volatility (Thorgeirsson, 2018; Gylfason and Zoega, 2018). Therefore, while other countries may experience economic volatility, it is likely to more acute in Iceland, but, of course, this volatility is what made it an interesting case study.

4. Results

The results section first presents the socio-technical review of the developments of Iceland's mobility sector, setting the scene for the study. With the context for the socio-ecological performance developments provided, the socio-ecological results are presented as an illustration of the effect of socio-technical developments on Iceland's mobility provisioning and its socio-ecological efficiency. Lastly, with historical developments tracked, we then peered into the future to investigate how various development pathways could impact the socio-ecological efficiency of Iceland's mobility sector.

4.1. Socio-technical review of passenger ground transport in iceland from 1995 to 2018

In performing the socio-technical review of Iceland's mobility system, four time periods were identified in the study period that saw unique development stages. In the following subsections, these periods are described, and data which provided a good representation of the time were shown. It should be noted though that these graphs are shown in each period, they also describe the entire study period and were provided for context over the 1995–2018 period and should be interpreted as such.

4.1.1. From the great depression to 1995

Before World War II, Iceland was still suffering from the Great Depression. The war acted as a catalyst for rapid change in Iceland. British and American occupation brought increased employment and economic opportunity, as the foreign armies could pay comparatively large sums for work. This influx of money transformed the country after the war. This development was aided by the entrance of cars and machines brought by the occupying forces, which were largely absent before the war but became plentiful post-war (Valsson, 2003). Car ownership rates rapidly rose, allowing for a sprawled urban development desired by the rapidly urbanized rural folk who had come to Reykjavik to work during the war, which also aligned with the fashionable urban design thinking of the time. From roughly 1945 to 1965, Reykjavik's population grew by approximately 70%, while the capital's urban area grew by 700% (Valsson, 2003). In the 1960s, a renewed effort to develop a comprehensive plan for the city was made, resulting in the 1962–1983 Master Plan based on Scandinavian low-rise apartment suburbs, American-based traffic modelling schemes, land use separation, and the core assumption that every household should own an automobile (Reynarsson, 1999). This led to a vicious cycle of sprawl, with increasingly large road infrastructure developed, requiring the pullback of buildings, leading to further sprawl. This pattern continued in the 1970s and 1980s, where car-orientated lifestyles became the norm and policies were implemented, affording the car special privileges. As Iceland increasingly commercialized and globalized in the 1980s, 1990s, and 2000s, shopping malls and big box grocery stores further aided in a car-focused development (Valsson, 2003). By 2005, from the 1940s, Reykjavik's population density had declined from 120 inhabitants per hectare to 36 (Mathiesen and Zaccariotto, 2014).

i. 1995 – 2002: A globalizing Iceland

The beginning of the study period was a time of rapid change in Iceland. The country had just entered European Economic Area (EEA) in 1994, and an era of globalization, neoliberalization, and commercialization was in full swing (Skaar Viken, 2011). The banking system became privatized, currency markets opened, and live foreign TV channels could air in the country for the first time. This period also followed shortly after the 1992 Rio Conference on Sustainable Development, and the Icelandic population was increasingly starting to recognize some of the social externalities associated harm with car-orientated development, such as noise and air pollution (Reynarsson, 1999). Iceland would go on to publish their first framework for sustainable development in 1998 and a new regional plan for Reykjavik, both with clearly stated goals to reduce car dependence, urban sprawl, and distance between homes and work, while increasing land use mix and the use of public transit and active modes (Government of Iceland, 1998; ; Valsson, 2003).

Conflicts between economic development, associated consumerism, and environmental visions in the mobility sector would surface, however, where the commercialization of the times led to a further prominence of shopping centres and park-and-shop grocery stores. These developments would lead to additional investments to increase road capacity and, contradictorily, were even part of the urban plan which set out to reduce car dependency (Valsson, 2003). As shown in Fig. 1, car ownership rates increased by 26% during the period, leading to increased mobility activity (Statistics Iceland, 2022a; OECD, 2022). This has a positive impact on accessibility, but this continued sprawl may have created the need to travel greater distances itself.

ii. 2003 – 2008: The rise to crisis

The failure of the sustainable mobility policies to have the intended positive environmental effects continued into the next period. Unbeknownst to those at the time, a new era of speculative investing had begun. Easy access to borrowing left banks competing to invest in increasingly high-risk investments (Danielsson and Zoega, 2009). This fuelled a real-estate bubble in Iceland, where unrealistic housing demand forecasts outpaced population growth, fuelling a construction boom (Mathiesen and Zaccariotto, 2014).

To compete for attractive investments, municipalities in Iceland made amendments to the Master plan, encouraging further speculative housing developments. During the six years leading up to the crash, Reykjavik's urban footprint expanded by 25%, exacerbating sprawl (Mathiesen and Zaccariotto, 2014). This paired investment craze and tossing of the plans was also seen in the transport sector, where over 220 km of roads and nine cloverleaf interchanges were built, while only 3 km of bike lanes were developed (Mathiesen and Zaccariotto, 2014), with the large sums invested in road projects during this time shown in Fig. 2 (Statistics Iceland 2022a). Excess consumption behaviour extended to households where car ownership increased in tandem during this time as shown in

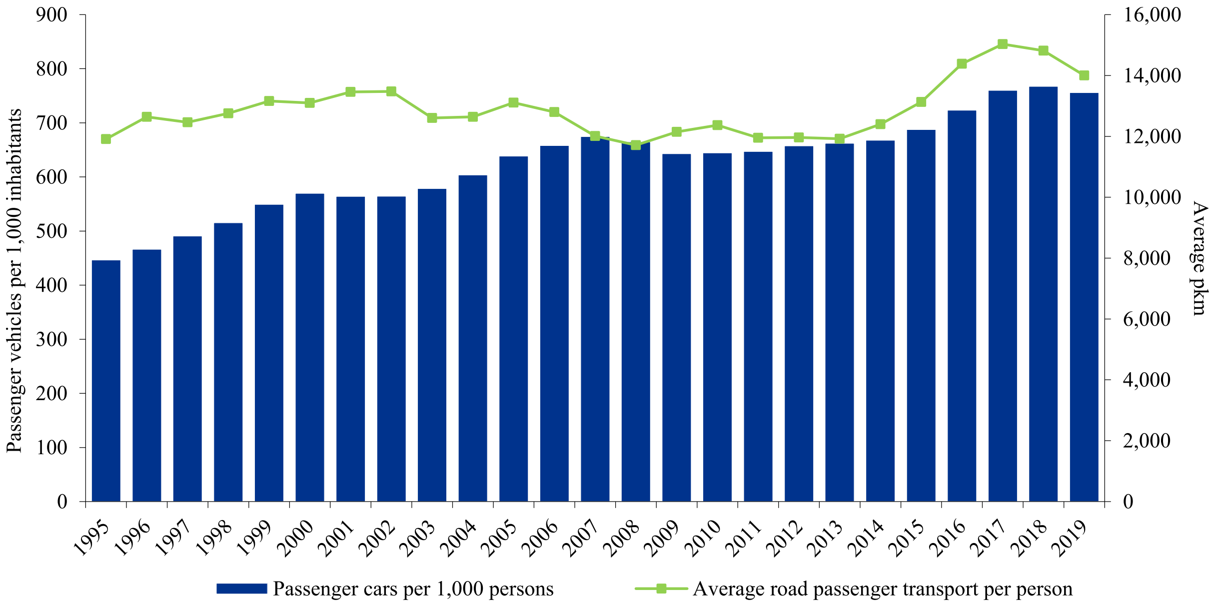

Fig. 1. Car ownership rates (left axis) and road transport activity (right axis) in Iceland from 1995 to 2018.

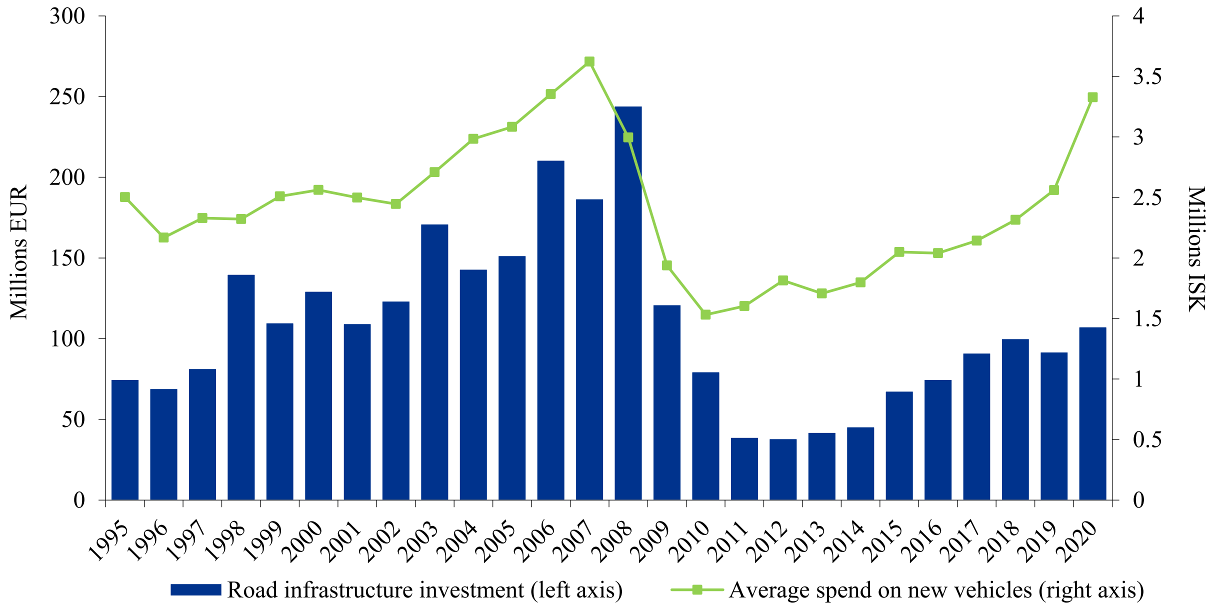

Fig. 2. Road infrastructure investments (left axis) and average household spend on new vehicles (right axis) in Iceland from 1995 to 2018.

Fig. 1 and the average price of a new vehicle purchase rose by almost 50% during this period (Statistics Iceland 2022a). Two positive social developments would occur over the period, however, where both air pollution exposure and road fatalities began to decrease after the government put its first law in place to measure and begin addressing air local air pollutants in 1998 (Alþingi, 1998). Significant infrastructure investments were also made to connect all population centres with >200 inhabitants with paved roads to increase road safety (where previously many gravel roads still existed) (Jóhannesson and Sigurbjarnarson, 2012). These changes can be seen in the Appendix.

iii. 2009 – 2012: Austerity after the crash and before the tourism boom

This rise in prosperity reversed rapidly in October 2008, however, when Iceland's three major banks all collapsed in the same week. (Danielsson and Zoega, 2009). Inflation rose to 16%, and with it came reduced purchasing power, lowered wages, and unemployment

(Ulfarsson et al., 2015). After years of unbridled prosperity and consumption, (transport) behaviour rapidly had to change in the face of a new reality.

Icelanders began travelling less, seeing public transport in a more positive light and working from home more often (Ulfarsson et al., 2015). Those in the suburbs were more intensely affected due to forced car use and were more likely to reduce their trip frequency (Ulfarsson et al., 2015). This consumption behaviour changed both at the government level, where Fig. 2 shows the decline in spending on infrastructure projects after the crash, as well as at the household level. Fig. 3 shows the change in household vehicle purchase behaviour, where the number of new vehicle registrations decreased by approximately two-thirds and the average weight of a new vehicle dropped by nearly 500 kg from 2008 to 2009 (Icelandic Transport Authority, 2022), as Land Cruisers were swapped out for Suzuki Swifts[1] (Gasnier, 2009; Gasneir, 2010).

vi. 2013 – 2018: Recovery: The rise of tourism and EVs

Towards the end of the previous period, several developments occurred that would come to define the final period described here. First was the eruption of Eyjafjallajökull in 2010, which ironically caused one of the most significant stoppages of air traffic since WWII but would play a role in influencing the rapid rise in air travel to Iceland (Keeling, 2020). In 2011, WOW Air opened, a low-cost air carrier which provided routes connecting North America and Europe. Alongside Iceland Air, Icelandic airlines began promoting Iceland as a hub and stopover destination. Paired with the rise in global tourism and Iceland's scenic landscapes, tourism in Iceland would rapidly rise, as shown in Fig. 4, where, by its peak in 2018, more than two million tourists would visit Iceland, equating to almost six times the island's population (Statistics Iceland, 2022a). This influx of tourists led to a booming economic recovery for the country, and soon, consumption would again begin to rise, as seen in Fig. 3, where the number of new vehicle registration would surpass even the times before the crash.

Before this peak, the City of Reykjavik established its new city plan in 2014, setting a vision for Reykjavik's future development, which would again focus on increased urban density, mixed land use, and promoting active and public transport modes (City of Reykjavik, 2014). This time, however, there were two additional pathways considered. The first was that the goal focused on reducing traffic during peak periods as opposed to just further increasing road capacity. The second was the option of emission-free vehicles. Where historical efforts to decarbonize transport through densification and reduced car ownership in Iceland could largely be seen as a failure (Sovacool et al., 2018), electrification provided a mass market path to decarbonization (Shafiei et al., 2017; Dillman et al., 2021). Previous efforts could not lean on new energy technologies which allowed for continued car ownership, whereas instead efforts to reduce GHG emissions in transport relied on a transition to diesel vehicles (Icelandic Ministry for the Environment, 2007), as shown in Fig. 4, which did not exactly represent a niche innovation by this time.

v. A brief look beyond 2018

In broad strokes, after 2018, the four primary developments which would influence Iceland's transport sector include the crash of WOW Air, the continued rise of electric vehicles, the discussions surrounding the development of a Bus Rapid Transit system, and, of course, the Covid-19 pandemic. First, the crash of WOW Air in 2019 had a significant impact on the Icelandic economy that had begun to specialize in tourism, leading to a 14% contraction in tourism that year (Central Bank of Iceland, 2022). Second, electric vehicles would continue to gain prominence, whereby in 2021, 64% of new vehicle registrations were EVs (BEV or PHEV) (EEA, 2022). Third, a Bus Rapid Transit (Borgarlina) system has been proposed in Reykjavik that could significantly promote greater shares of public transport in travel modes and aims to support nodal densification in Reykjavik. Full funding for this project has not yet been confirmed, however, and it would not be completed until after 2026, so its impacts are still largely uncertain though some early estimates of its potential effects have been made (Mannvit, 2020). Lastly, were the effects of Covid-19. During the pandemic, mobility was one of the sectors that saw the greatest reductions in consumption, and global tourism was decimated (Keeling, 2020). It further influenced how people get to work (or work remotely) and has since lowered public transit mode shares globally (Zhang and Zhang, 2021).

Fig. 5 synthesized the developments across periods discussed in the socio-technical review and mapped them according to the MLP framework. The purpose of this image is to show how landscape changes (such as the banking boom and crisis), internal system changes (e.g. policies), and innovations (e.g. EVs) influenced Iceland's mobility provisioning system. The discussion will use this image as a reference in its review of Iceland's socio-technical developments connected to the socio-ecological performance of the system's provisioning.

4.2. Socio-ecological performance over study period

With Iceland's mobility system's landscape, regime, and innovation developments described for context, how these developments influenced sustainability performance over time was assessed. Using the indicators specified in the methodology and the socio-ecological performance measured as described in the Appendix, Iceland's mobility sector's proximity to a 'safe' (below the red vertical line) and 'just' (above the green horizontal line) space over time was illustrated in Fig. 6. Rapid social achievement was seen from 1995 to 2003, with a slight decrease in ecological overshoot. This would change between 2003 and 2008, where while social

[1] Where the models labelled here represent the most purchased vehicle in 2008 and 2009, respectively.

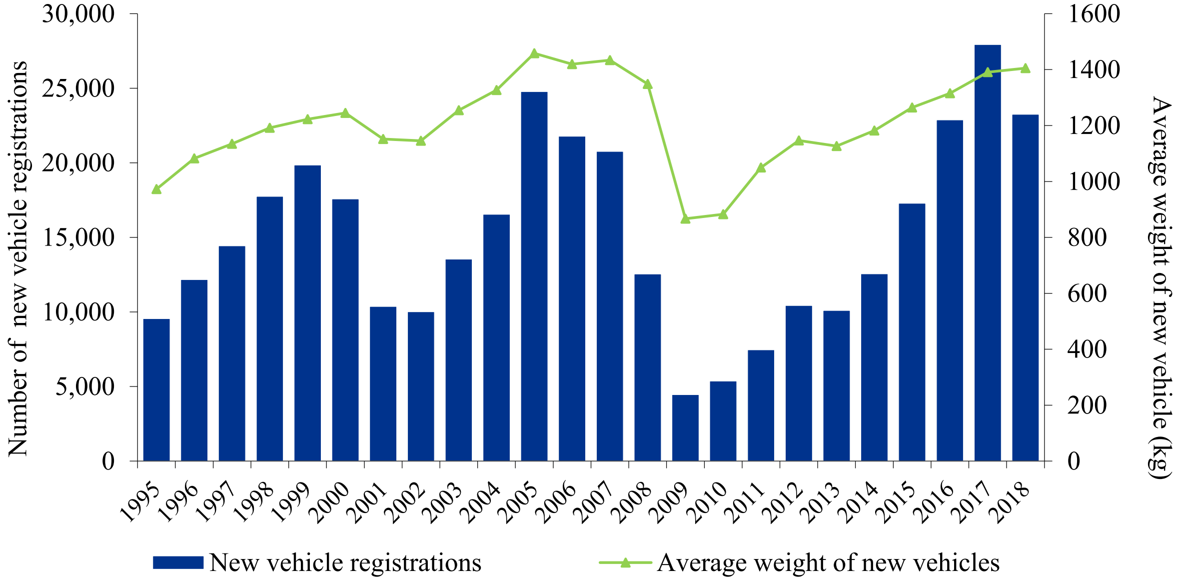

Fig. 3. New vehicle registrations (left axis) and the average weight of newly purchased vehicles (right axis) in Iceland from 1995 to 2018.

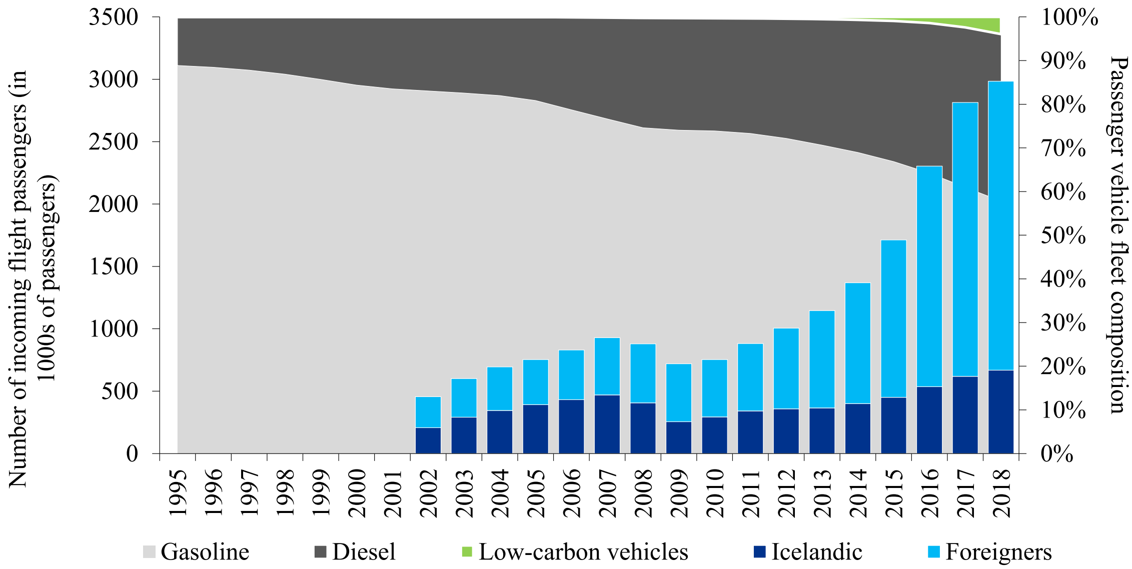

Fig. 4. Number of incoming flight passengers by residency, Icelandic or Tourist[21] (left axis), and the vehicle fleet composition (right axis) in Iceland from 2002 to 2018.

achievement rose during the period, rapid consumption would lead to a much more significant rise in ecological overshoot, reaching a peak of almost 4.5 in 2006, leading to an ecological intensity which outpaced improvements in social provisioning. After the economic crash, from 2009 to 2013, social progress and ecological overshoot would similarly stagnate due to austere economic and transport activity reductions. This would start to change towards the end of this period, as the final period began, where economic recovery would lead to further strides in social provisioning whilst ecological overshoot would similarly rise.

5. Discussion

This work used socio-technical transition theory to narrate and quantify changes to Iceland's mobility provisioning system from 1995 to 2018 while mapping the system's proximity to the defined 'safe' and 'just' space. Fig. 6 showed how over the entire study period, Iceland's mobility provisioning never entered this space, though by the end of the period it was close to entering the defined 'just' space. The linkage of these two results is a first data point which supports O'Neill et al. (2018) hypothesis, that current

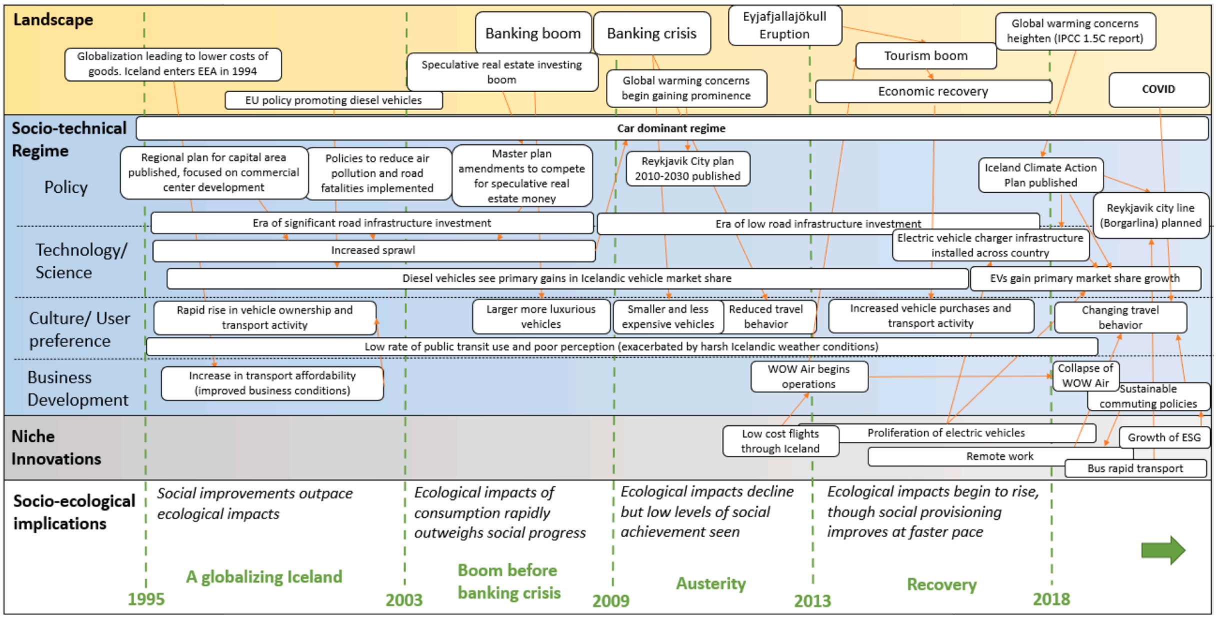

Fig. 5. Multi-level perspective mapping of socio-technical developments in Iceland from 1995 to 2018.

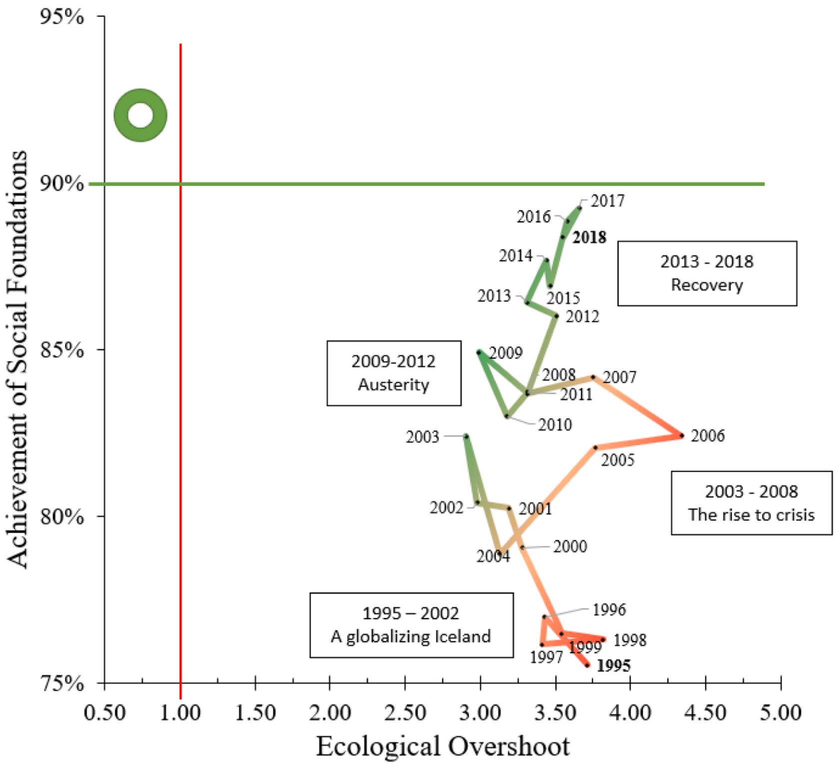

Fig. 6. Socio-ecological performance of Iceland's mobility sector from 1995 to 2018. The Doughnut represents the 'safe and just' space which should be the goal of sustainable development for the mobility sector.

[2] Where data was only available for incoming flights starting in 2002.

provisioning systems are currently not satisfying the needs of its citizens within ecological limits. Iceland's mobility provisioning far exceeded the set ecological ceilings while having close, though not fully, achieving the contextually defined 'just' state. This work provides insight into the tie between the economic landscape and mobility stocks/behaviour, and how these, in turn, influence social achievement and ecological overshoot. These findings illustrate the strength and importance of combining socio-technical transition frameworks with strong sustainability for improved clarity on the *whys* and *hows* of a just energy transition.

5.1. Socio-technical developments and socio-ecological performance

The socio-technical review provided insights into all three levels of the MLP. First, it illustrated the significant impact economic, broader policy, and unexpected (shocks) landscape developments can have on a regime and its socio-ecological performance. Iceland provided an excellent case study for studying the influence of economic changes on a system due to the high economic volatility seen from 1995 to 2018. Iceland's rapid liberalization, banking boom and bust, and final economic recovery due to an explosive rise in tourism, could all be seen in Iceland's mobility transformations. For example, where Iceland's liberalization led to cheaper goods, accessibility and affordability of transport rose with higher vehicle ownership rates (Huijbens and Þorsteinsson, 2010). As healthy economic growth gave way to excess, however, spikes in vehicle weight and costs as well as investment in sprawling infrastructure led to increased ecological overshoot with low social gain. Economic hardship after the banking crisis led to a plummet in new vehicles, their average weight, and to a lesser extent, transport behaviour (Ulfarsson et al., 2015). This rapid rise and fall of economic well-being and consumer behaviour drew two interesting conclusions. First, it provides an example of the varying elasticities between needs-satisfying activities and need-satisfiers (Brand-Correa et al., 2020), where, after the crash, mobility needs still needed to be satisfied, and transport activity only saw a small dip. Whether these needs were satisfied by a Land Cruiser, or a Suzuki Swift, proved to be more malleable. This has far-reaching implications in terms of the ability to de-escalate need-satisfiers. Regarding this point, while we were not able to investigate this more deeply in this work, worth note is that once larger or less efficient vehicles are purchased, they then become part of the evolving stock, and thus the influence of purchases of vehicles such as SUVs during a time of economic peaks can then come to influence sustainability outcomes long into the future (Jacobsen and van Benthem, 2015). Second, this drop in consumption aided in reaching the lowest point of ecological overshoot over the study period, but not by much, and this is notable because it took one of the greatest economic crashes in history to reach this point. While the effects of this economic crash led to a drastic year-by-year drop in overshoot, its effect was neither permanent nor close to sufficient in its ability to enter a 'safe' mobility space (as shown in Fig. 6). This is reminiscent of Covid's drastic, yet insufficient, in terms of the time and scale of environmental impact reduction in the transport sector (e.g. Rojas et al., 2022).

The effect of exogenous "shocks" such as Covid on the regime was another interesting finding, where events, such as the Eyjafjallajökull eruption that aided in promoting a massive tourism boom that led to economic recovery and rebounding consumption, were found to have significant system impacts. This reinforces transition theory which points to shocks as regime-changing catalysts (e.g. Hermwille, 2016; Simpson, 2019). Lastly, other landscape developments, such as EU-level policies and climate change concerns, had significant regime development impacts. For example, where the share of diesel vehicles in Iceland's vehicle fleet went from ~10% to ~40% from 1995 to 2018, or to mitigate GHG emissions, Iceland's established incentives to increase EV uptake which we have noted for its success in terms of penetration rate (Government of Iceland, 2019).

Second, the review showed how provisioning systems (regimes) can change over time. The rise and fall of ecological overshoot associated with vehicle stock changes (in the form of high/low new vehicle purchases and new vehicle weight) and changes in transport behaviour illustrate how changes in the system itself affect ecological outcomes. Further, policies at the regime level, such as those with the goal of decreasing traffic fatalities or air pollution were shown to be effective in determining social outcomes. The results also reinforce findings on the challenges involved with overcoming infrastructural lock-in, however, particularly in the mobility sector (e.g. Næss and Vogel, 2012; Driscoll, 2014; Klitkou et al., 2015; Seto et al., 2016; Mattioli et al., 2020). In terms of changes that can occur, transitioning vehicles was found to be easier than transitioning infrastructure and car dependence in this case study. Since the 1990s, Icelandic planning and policy documents have stated goals to increase urban density, public transport use, and reduce car ownership rates (Valsson, 2003; Government of Iceland, 1998), yet the data presented in this work illustrate the failure in achieving these goals, where car ownership rates refused to decline while rates of EV ownership increased exponentially. Driscoll et al. (2012) saw the potential for this in the wake of the EV transition and their predictions that the EV transition would serve to reinforce a car-centric development by appearances has come true (Dillman et al., 2020b). These results reinforce the finding of other transition studies that policymakers cannot steer transitions by force of will against cultural practices, neoliberal growth agendas, and legacy systems (Smith and Stirling, 2007; Geels et al., 2015). For example, where Pichler et al. (2021) found that EU automotive policy industrial policy at best may serve to improve the efficiency of transport systems, but at worst conserves the unsustainable configuration of the automobile-dominated mobility regime, leading to the relative but not strong sustainability direction we have discussed as needed to remain within the planetary boundaries.

Against this resistance, more advanced socio-technical regime transition approaches may be needed, where policy, technology, and business developments should work in tandem to promote cultural changes. In Iceland, this may mean the need for collaborations across provisioning system components, for example when implementing the planned bus rapid transit system, where coordinated policy, business, and technological innovation may be required to successfully bring about a public transit transition which has been difficult to achieve in Iceland (Mattioli et al., 2020; Heinonen et al., 2019).

Lastly, this work showed the influence tangential and inter-regime innovations can have on provisioning. This was seen largely in the last recovery period, where low-cost flights to Iceland (a business model innovation) and electric vehicle innovations led to an economic recovery which served to boost both social achievement as well as ecological overshoot. This period showed what perhaps would be the start of a “green growth” transition, where GDP growth saw relative decoupling with ecological impact.

5.2. Connecting socio-technical transitions and ‘strong’ sustainability

As a part of a future research agenda, we argue for a transdisciplinary, synergistic bridging of socio-technical studies and strong sustainability frameworks. If the two fields were written about separately in this work, portions of meaning from each perspective would be stripped. If this article focused solely on the transformations to Iceland’s mobility regime, there would be a lacking frame of reference to understand the scale of these developments. The strong sustainability framing gives the means to measure this scale, yet without the context of the socio-technical developments, the results in Fig. 6 would appear to bounce around without meaning and void of real-world context. Using socio-technical transition theory to tell the story of Iceland’s mobility sector transition allowed much deeper insight into *why* developments occurred than sustainability indices built in a vacuum. Thus, as opposed to the ‘reconfiguration’ perspective (e.g. Geels and Turnheim, 2022; Geels et al., 2015) that socio-technical studies position apart from strong sustainability perspectives, we instead see transition studies as the *how* and *why* of transformations and the goal of achieving strong sustainability as the *what*.

The interplay between socio-technical transitions and strong sustainability also reveals the complexity of achieving truly sustainable and just mobility systems. While technological advancements, such as the penetration of electric vehicles, can contribute to reducing ecological impacts, they alone may not be sufficient to ensure a just transition (Sovacool et al., 2019; Schwanen, 2021; Dillman, 2021). A more holistic approach that acknowledges the need for transformative changes in infrastructure, culture, and policy is essential, which explains our bridged analytical approach. For instance, promoting active and public transportation, enhancing urban planning to reduce sprawl and promote compact development, and implementing policies that discourage excessive car ownership may be necessary to create a genuinely sustainable and just mobility system. A transition study without grounding in strong sustainability and missing social aspects may lack the ability to capture such notions (Susur and Karakaya, 2021). Additionally, it is crucial to consider the potential rebound effects that technological advancements can bring (Feola, 2020; Rietveld 2011), such as increased energy consumption due to the perceived environmental benefits of electric vehicles (Dillman, 2021; Dillman et al., 2021a,b; Powell et al., 2022). By integrating socio-technical transition theory and strong sustainability frameworks, researchers and policymakers can better understand the underlying dynamics driving change in mobility systems and identify more effective strategies to achieve just and sustainable transitions.

5.3. Future research

Future research can build on this study by expanding the application of the framework and addressing existing limitations. To further explore the integration of socio-technical transition theory and strong sustainability frameworks, researchers could study different contexts and focus on significant transition events, where this study largely focused on the volatile economic landscape developments, but other studies could focus on more specific and large-scale technological transitions. Additionally, addressing data limitations and incorporating more diverse socio-ecological indicators can enhance the accuracy of performance assessments, as this study was limited by the availability of Icelandic data.

Investigating the role of transformative changes in infrastructure, culture, and policy is additionally essential for understanding how to achieve the strong sustainability transition we suggest is needed. Future studies could further examine other provisioning systems, such as food or housing, to gain a comprehensive understanding of the underlying dynamics driving change and the potential pathways for achieving sustainable and just transitions. These expanded directions could serve to on the existing knowledge base, promoting greater integration of social and ecological aspects into transition studies, as well as contribute valuable insights for policymakers and stakeholders seeking to foster a just transition of human systems.

6. Conclusion

We conducted this research to understand how Iceland’s mobility provisioning changed over time and how these changes affected the system’s strong sustainability performance. By combining the multi-level perspective and provisioning system concepts, we tracked Iceland’s mobility provisioning regime from 1995 to 2018 and explored the dynamics of the country’s development over this period. Our research established a safe and just space for Icelandic mobility and discovered that although Iceland came close to achieving the just space, it never entered the defined space. Throughout the study, ecological overshoot exceeded the defined safe space, which aligns logically with Iceland’s high income and high consumption status. Socio-ecological performance fluctuated significantly throughout the period, however. We found that economic landscape developments associated with two economic booms and one economic downturn had a significant impact on ecological performance and, to a lesser extent, social performance. Increased ecological overshoot coincided with increased mobility activity and new vehicle purchases during economic booms, particularly the boom preceding the banking crisis where overshoot increased nearly 50% over the two-year period from 2004 to 2006, while the economic downturn negatively impacted mobility poverty aspects such as accessibility and affordability. Our results demonstrate the potential synergies of merging socio-technical transition theory and strong sustainability perspectives for just transition studies. By studying why systems change over time due to landscape, innovation, and internal reconfiguration changes, and how such changes can impact strong sustainability performance, we can explore the co-benefits or detriments of development pathways. We believe that applying this approach to other provisioning systems at various temporal and spatial scales is an important route forward in research aimed at understanding provisioning systems, their change dynamics, and ultimately how their socio-ecological efficiencies can be improved.

Declaration of Competing Interest

The authors declare no conflict of interests exist regarding this work.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eist.2023.100755.

References

Akenji, L., Bengtsson, M., Toivio, V., Lettenmeier, M., Fawcett, T., Parag, T., 2021. 1.5-degree lifestyles: Towards a fair Consumption Space For all. Hot or Cool Institute, Berlin. ISBN 978-3-98664-002-6.
Alþingi, 1998. Lög Um Hollustuhætti Og Mengunarvarnir. Paliamanet of Iceland. Retrieved from Alþingi. https://www.althingi.is/altext/stjt/1998.007.html.
Apte, J.S., Bombrun, E., Marshall, J.D., Nazaroff, W.W., 2012. Global intraurban intake fractions for primary air pollutants from vehicles and other distributed sources. Environ. Sci. Technol. 3415–3423. https://doi.org/10.1021/es204021h.
Brand-Correa, L.I., Mattioli, G., Lamb, W.F., Steinberger, J.K., 2020. Understanding (and tackling) need satisfier escalation. Sustainability: Sci., Practice Pol. 16 (1), 309–325. https://doi.org/10.1080/15487733.2020.1816026.
Büchs, M., 2021. Sustainable welfare: how do universal basic income and universal basic services compare? Ecological Econ. 189, 107152 https://doi.org/10.1016/j.ecolecon.2021.107152.
Central Bank of Iceland, 2022. Economy of Iceland. The Central Bank of Iceland., Reykjavik. ISSN 2772-0829.
Chancel, L., Piketty, T., Saez, E., Zucman, G., 2022. World Inequality Report 2022. World Inequality Lab wir2022.wid.world.
Clarke, J., Heinonen, J., Ottelin, J., 2017. Emissions in a decarbonised economy? Global lessons from a carbon footprint analysis of Iceland. J. Clean. Prod. 166, 1175–1186.
Collin-Lange, V., 2014. 'My car is the best thing that ever happened to me' automobility and novice drivers in Iceland. Young 22 (2), 185–201.
Coote, A., 2021. Universal basic services and sustainable consumption. Sustainability: Sci., Practice Pol. 17 (1), 32–46.
Czepkiewicz, M., Árnadóttir, Á., Heinonen, J., 2019. Flights dominate travel emissions of young urbanites. Sustainability 22 (11), 6340. https://doi.org/10.3390/su11226340.
Czepkiewicz, M., Heinonen, J., Ottelin, J., 2018. Why do urbanites travel more than do others? A review of associations between urban form and long-distance leisure travel. Environ. Res. Lett. 13 (7), 073001. doi.org/10.1088/1748-9326/aac9d2.
Danielsson, J., Zoega, G., 2009. The Collapse of a Country. Institute of Economic Studies Discussion Paper. Accessed at. https://www.riskresearch.org/files/DanielssonZoega2009.pdf.
Dietz, T., Rosa, E.A., York, R., 2012. Environmentally efficient well-being: is there a Kuznets curve? Appl. Geogr. 32 (1), 21–28. https://doi.org/10.1016/j.apgeog.2010.10.011.
Dillman, K., 2021. Electric vehicles, a silver bullet or merely a piece to the puzzle of an intergenerationally sustainable urban mobility sector? PhD dissertation, Faculty of Civil and Environmental Engineering. University of Iceland. https://hdl.handle.net/20.500.11815/2747.
Dillman, K.J., Czepkiewicz, M., Heinonen, J., Davíðsdóttir, B., 2021a. A safe and just space for urban mobility - a framework for sector-based sustainable consumption corridor development. Global Sustainability 1–42.
Dillman, K.J., Fazeli, R., Shafiei, E., Jónsson, J.Ö., Haraldsson, H.V., Davíðsdóttir, B., 2021b. Spatiotemporal analysis of the impact of electric vehicle integration on Reykjavik's electrical system at the city and distribution system level. Util. Policy 68, 101145. https://doi.org/10.1016/j.jup.2020.101145.
Dillman, K.J., Heinonen, J., Davíðsdóttir, B., 2023. A development of intergenerational sustainability indicators and thresholds for mobility system provisioning: a socio-ecological framework in the context of strong sustainability. Environ. Sustainability Indicators, 100240. https://doi.org/10.1016/j.indic.2023.100240.
Dillman, K., Árnadóttir, Á., Heinonen, J., Czepkiewicz, M., Davíðsdóttir, B., 2020a. Review and meta-analysis of EVs: embodied emissions and environmental breakeven. Sustainability 12 (22), 9390.
Dillman, K., Fazeli, R., Czepkiewicz, M., Heinonen, J., Árnadóttir, Á., 2020b. Decarbonization Scenarios for Reykjavik's passenger transport: The combined Effects of Behavioral Changes and Technological Developments. Rannsóknasjóðs Vegagerðarinnar, Reykjavik.
Driscoll, P.A., 2014. Breaking carbon lock-in: path dependencies in large-scale transportation infrastructure projects. Plan. Pract. Res. 29 (3), 317–330. https://doi.org/10.1080/02697459.2014.929847.
Driscoll, P.A., Theodórsdóttir, Á., Richardson, T., Mguni, P., 2012. Is the future of mobility electric? Learning from contested storylines of sustainable mobility in Iceland. Eur. planning stud. 20 (4), 627–639. https://doi.org/10.1080/09654313.2012.665036.
Duffy, S., Northey, G., van Esch, P., 2017. Iceland: how social mechanisms drove the financial collapse and why it's a wicked problem. J. Soc. Mark 7 (3), 330–346. https://doi.org/10.1108/JSOCM-12-2016-0079.
EEA. (2022). *New registrations of electric vehicles in Europe*. Retrieved from European Environmental Agency: https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles.
Fanning, A.L., O'Neill, D.W., Hickel, J., Roux, N, 2022. The social shortfall and ecological overshoot of nations. Nature Sustainability 5 (1), 26–36. https://doi.org/10.1038/s41893-021-00799-z.
Fanning, A.L., O'Neill, D.W., Büchs, M., 2020. Provisioning systems for a good life within planetary boundaries. Glob. Environ. Chang. 64, 102135.
Feola, G., 2020. Capitalism in sustainability transitions research: time for a critical turn? Environ. Innov. Soc. Transit. 35, 241–250. https://doi.org/10.1016/j.eist.2019.02.005.

Fuchs, D., Sahakian, M., Gumbert, T., Di Giulio, A., Maniates, M., Lorek, S., Graf, A., 2021. Consumption corridors: Living a good Life Within Sustainable Limits. Routledge.
Gasnier, M. (2009, Jan 5). *Iceland 6 months 2008: toyota Yaris & Land Cruiser dominate*. Retrieved from Best seeling cars blog: Accessed at: https://bestsellingcarsblog.com/2009/01/iceland-6-months-2008-yaris-land-cruiser-dominate/.
Gasnier, M. (2010, Jan 29). *Iceland 2009: suzuki Swift and Subaru Legacy top dismal market*. Retrieved from Best selling cars blog: Accessed at: https://bestsellingcarsblog.com/2010/01/iceland-2009-suzuki-swift-and-subaru-legacy-top-dismal-market/.
Geels, F.W., 2018. Low-carbon transition via system reconfiguration? A socio-technical whole system analysis of passenger mobility in Great Britain (1990–2016). Energy res. soc. sci. 46, 86–102. https://doi.org/10.1016/j.erss.2018.07.008.
Geels, F.W., 2019. Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. Curr. Opin. Environ. Sustain. 39, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009.
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Res. Poli. 36 (3), 399–417.
Geels, F.W., Turnheim, B., 2022. The Great Reconfiguration. Cambridge University Press.
Geels, F.W., McMeekin, A., Mylan, J., Southerton, D., 2015. A critical appraisal of Sustainable Consumption and Production research: the reformist, revolutionary and reconfiguration positions. Glob. Environ. Chang. 34, 1–12. https://doi.org/10.1016/j.gloenvcha.2015.04.013.
Gingrich, S., Krausmann, F., 2018. At the core of the socio-ecological transition: agroecosystem energy fluxes in Austria 1830–2010. Sci. Total Environ. 645, 119–129. https://doi.org/10.1016/j.scitotenv.2018.07.074.
Government of Iceland. (1998, July 7). *Sjálfbær þróun í íslensku samfélagi - framkv.áætlun til aldamóta*. Retrieved from Government of Iceland: https://www.stjornarradid.is/efst-a-baugi/frettir/stok-frett/1998/07/07/Sjalfbaer-throun-i-islensku-samfelagi-framkv.aaetlun-til-aldamota/.
Government of Iceland. (2019, June 4). *Markviss uppbygging innviða vegna orkuskipta í samgöngum*. Retrieved from Government of Iceland: Accessed at: https://www.stjornarradid.is/efst-a-baugi/frettir/stok-frett/2019/10/22/Styrkjum-uthlutad-til-uppsetningar-hledslustodva-vid-gististadi-um-land-allt/.
Groß, R., Streeck, J., Magalhaes, N., Krausmann, F., Haberl, H., Wiedenhofer, D., 2022. How the European recovery program (ERP) drove France's petroleum dependency, 1948–1975. Environ. Innov. Soc. Transit. 42, 268–284. https://doi.org/10.1016/j.eist.2022.01.002.
Guinée, J.B., de Koning, A., Heijungs, R., 2022. Life cycle assessment-based absolute environmental sustainability assessment is also relative. J. Ind. Ecol. 26 (3), 673–682. https://doi.org/10.1111/jiec.13260.
Gupta, J., Liverman, D., Prodani, K., Aldunce, P., Bai, X., Broadgate, W., Inoue, C., 2022. Conceptualizing Earth system justice. OSF preprint. https://doi.org/10.31235/osf.io/b36tc.
Gylfason, T., Zoega, G., 2018. The dutch disease in reverse: iceland's natural experiment. In: Paganetto, L. (Ed.), Getting Globalization Right. Springer, Cham, pp. 13–36. https://doi.org/10.1007/978-3-319-97692-1_2.
Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D., Fischer-Kowalski, M., 2019. Contributions of sociometabolic research to sustainability science. Nat. Sustain. 2, 173–184. https://doi.org/10.1038/s41893-019-0225-2.
Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., Mayer, A., 2020. A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. Environ. Res. Lett. 15 (6), 065003 https://doi.org/10.1088/1748-9326/ab842a.
Heinonen, J., Czepkiewicz, M., Árnadóttir, Á., Ottelin, J., 2021. Drivers of car ownership in a car-oriented city: a mixed-method study. Sustainability 13 (2), 619. https://doi.org/10.3390/su13020619.
Heinonen, J., Olson, S., Czepkiewicz, M., Árnadóttir, Á., Ottelin, J., 2022. Too much consumption or too high emissions intensities? Explaining the high consumption-based carbon footprints in the Nordic countries. Kankyo Hen'igen Kenkyu. https://doi.org/10.1088/2515-7620/aca871 in press.
Hermwille, L., 2016. The role of narratives in socio-technical transitions—Fukushima and the energy regimes of Japan, Germany, and the United Kingdom. Energy Res. Soc. Sci. 11, 237–246. https://doi.org/10.1016/j.erss.2015.11.001.
Hertwich, E.G., 2021. Increased carbon footprint of materials production driven by rise in investments. Nat. Geosci. 14 (3), 151–155. https://doi.org/10.1038/s41561-021-00690-8.
Heyen, D.A., 2022. Social justice in the context of climate policy: systematizing the variety of inequality dimensions, social impacts, and justice principles. Climate Policy 1–16.
Hickel, J., 2016. The true extent of global poverty and hunger: questioning the good news narrative of the Millennium Development Goals. Third World Q. 37 (5), 749–767. https://doi.org/10.1080/01436597.2015.1109439.
Hickel, J., 2018. Is it possible to achieve a good life for all within planetary boundaries? Third World Q. 40 (1), 18–35. https://doi.org/10.1080/01436597.2018.1535895.
Hickel, J., Kallis, G, 2020. Is green growth possible? New political econ. 25 (4), 469–486.
Hickel, J., Brockway, P., Kallis, G., Keyßer, L., Lenzen, M., Slameršak, A., Ürge-Vorsatz, D., 2021. Urgent need for post-growth climate mitigation scenarios. Nature Energy 6 (8), 766–768. https://doi.org/10.1038/s41560-021-00884-9.
Hickel, J., Kallis, G., Jackson, T., O'Neill, D., Schor, J., Steinberger, J., Ürge-Vorsatz, D., 2022. Degrowth can work — Here's how science can help. Nature 612, 400–403. https://doi.org/10.1038/d41586-022-04412-x.
Hillman, K.M., Sandén, B.A., 2008. Exploring technology paths: the development of alternative transport fuels in Sweden 2007–2020. Technol. Forecast. Soc. Change 75 (8), 1279–1302. https://doi.org/10.1016/j.techfore.2008.01.003.
Holden, E., Linnerud, K., Banister, D., 2013. Sustainable passenger transport: back to Brundtland. Transp. Res. Part A Pol. Pract. 54, 67–77. https://doi.org/10.1016/j.tra.2013.07.012.
Huijbens, E., Þorsteinsson, H.F., 2010. Letters from Iceland. Political Insight 1 (1).
Icelandic Ministry for the Environment, 2007. Iceland's Climate Change Strategy. Reykjavik. Accessed at. https://www.government.is/media/umhverfisraduneyti-media/media/PDF_skrar/Stefnumorkun_i_loftslagsmalum_enlokagerd.pdf. Icelandic Ministry for the Environment.
Icelandic Transport Authority. (2022). *Tölfræði*. Retrieved from Icelandic Transport Authority: https://bifreidatolur.samgongustofa.is/#tolfraedi.
IEA, 2022. Global EV Outlook 2022. IEA, Paris. https://www.iea.org/reports/global-ev-outlook-2022. License: CC BY 4.0.
Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., Hertwich, E.G., 2016. Environmental impact assessment of household consumption. J. Ind. Ecol. 20 (3), 526–536. https://doi.org/10.1111/jiec.12371.
Jacobsen, M.R., Van Benthem, A.A., 2015. Vehicle scrappage and gasoline policy. Am. Econ. Rev. 105 (3), 1312–1338. https://doi.org/10.1257/aer.20130935.
Jenkins, K., Sovacool, B.K., McCauley, D., 2018. Humanizing sociotechnical transitions through energy justice: an ethical framework for global transformative change. Energy Policy 117, 66–74. https://doi.org/10.1016/j.enpol.2018.02.036.
Jóhannesson, H., Sigurbjarnarson, V., 2012. Icelandic Road Infrastructure. Akureyri. ISSN 1670-8873: RHA-University of Akureyri Research Centre.
Johnsen, G., 2014. Bringing Down the Banking system: Lessons from Iceland. Springer.
Keeling, D.J., 2020. Transport geography in Iceland. J. Transp. Geogr. 89, 102875 https://doi.org/10.1016/j.jtrangeo.2020.102875.
Klitkou, A., Bolwig, S., Hansen, T., Wessberg, N., 2015. The role of lock-in mechanisms in transition processes: the case of energy for road transport. Environ. Innov. Soc. Transit. 16, 22–37.
Knight, K.W., Rosa, E.A., 2011. The environmental efficiency of well-being: a cross-national analysis. Soc. Sci. Res. 40 (3), 931–949. https://doi.org/10.1016/j.ssresearch.2010.11.002.
Köhler, J., Geels, F.W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Wells, P., 2019. An agenda for sustainability transitions research: state of the art and future directions. Environ. Innov. Soc. Transit. 31, 1–32.
Lamb, W.F., Steinberger, J.K., 2017. Human well-being and climate change mitigation. Wiley Interdiscip. Rev. Clim. Change 8 (6), e485. https://doi.org/10.1002/wcc.485.
Lamb, W.F., Steinberger, J.K., Bows-Larkin, A., Peters, G.P., Roberts, J.T., Wood, F.R., 2014. Transitions in pathways of human development and carbon emissions. Environ. Res. Lett. 9 (1), 014011 https://doi.org/10.1088/1748-9326/9/1/014011.

Lettenmeier, M., Liedtke, C., Rohn, H., 2014. Eight tons of material footprint—Suggestion for a resource cap for household consumption in Finland. Resources 3 (3), 488–515.
Lin, X., Sovacool, B.K., 2020. Inter-niche competition on ice? Socio-technical drivers, benefits and barriers of the electric vehicle transition in Iceland. Environ. Innov. Soc. Transit. 35, 1–20. https://doi.org/10.1016/j.eist.2020.01.013.
Litman, T., 2021. Transportation Affordability. Victoria Transport Policy Institute. Accessed at. https://www.vtpi.org/affordability.pdf.
Lucas, K., Mattioli, G., Verlinghieri, E., Guzman, A., 2016. Transport poverty and its adverse social consequences. In: Proceedings of the institution of civil engineers-transport, 169. Thomas Telford Ltd, pp. 353–365.
Mannvit, 2020. Borgarlínan Socioeconomic Analysis. Mannvit. Accessed at. https://wp.borgarlinan.is/wp-content/uploads/2020/11/a133201_report-socioeconomic-analysis_final.pdf.
Markard, J., Raven, R., Truffer, B., 2012. Sustainability transitions: an emerging field of research and its prospects. Res. Policy 41, 955–967.
Mathiesen, A., Zaccariotto, G., 2014. *Scarcity in Excess: the Built Environment and the Economic Crisis in Iceland*. Actar D, Inc.
Mattioli, G., 2016. Transport needs in a climate-constrained world. A novel framework to reconcile social and environmental sustainability in transport. Energy Res. Soc. Sci. 18, 118–128. https://doi.org/10.1016/j.erss.2016.03.025.
Mattioli, G., Lucas, K., Marsden, G., 2017. Transport poverty and fuel poverty in the UK: from analogy to comparison. Transp. Policy (Oxf) 59, 93–105. doi.org/10.1016/j.tranpol.2017.07.007.
Mattioli, G., Roberts, C., Steinberger, J.K., Brown, A., 2020. The political economy of car dependence: a systems of provision approach. Energy Res. Soc. Sci. 66, 101486 https://doi.org/10.1016/j.erss.2020.101486.
Millward-Hopkins, J., Steinberger, J.K., Rao, N.D., Oswald, Y., 2020. Providing decent living with minimum energy: a global scenario. Glob. Environ. Chang. 65, 102168 https://doi.org/10.1016/j.gloenvcha.2020.102168.
Næss, P., Vogel, N., 2012. Sustainable urban development and the multi-level transition perspective. Environ. Innov. Soc. Transit. 4, 36–50. https://doi.org/10.1016/j.eist.2012.07.001.
O'Neill, D.W., Fanning, A.L., Lamb, W.F., Steinberger, J.K., 2018. A good life for all within planetary boundaries. Nat. sustainability 1 (2), 88–95.
OECD. (2022). *Passenger transport*. Retrieved from OECD.stat: https://stats.oecd.org/.
Pichler, M., Krenmayr, N., Schneider, E., Brand, U., 2021. EU industrial policy: between modernization and transformation of the automotive industry. Environ. Innov. Soc. Transit. 38, 140–152. https://doi.org/10.1016/j.eist.2020.12.002.
Powell, S., Cezar, G.V., Min, L., Azevedo, I.M., Rajagopal, R., 2022. Charging infrastructure access and operation to reduce the grid impacts of deep electric vehicle adoption. Nat. Energy 7 (10), 932–945. https://doi.org/10.1038/s41560-022-01105-7.
Rammelt, C., Gupta, J., Liverman, D., Scholtens, J., Ciobanu, D., Abrams, J., Inoue, C., 2022. Impacts of Meeting Minimum Access on Critical Earth Systems amidst the Great Inequality. Nat. Sustain. https://doi.org/10.1038/s41893-022-00995-5.
Rao, N.D., Min, J., 2018. Decent living standards: material prerequisites for human wellbeing. Soc. Indic. Res. 138 (1), 225–244. https://doi.org/10.1007/s11205-017-1650-0.
Raworth, K., 2017. A doughnut for the anthropocene: humanity's compass in the 21st century. Lancet Planet Health e48–e49.
Reynarsson, B., 1999. The planning of Reykjavik, Iceland: three ideological waves-a historical overview. Planning Perspectives 14 (1), 49–67. https://doi.org/10.1080/026654399364346.
Rietveld, P., 2011. Telework and the transition to lower energy use in transport: on the relevance of rebound effects. Environ. Innov. Soc. Transit. 1 (1), 146–151. https://doi.org/10.1016/j.eist.2011.03.002.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F., Lambin, E., Nykvist, B., 2009. Planetary boundaries: exploring the safe operating space for humanity. Ecol. Soc. 14 (2).
Rojas, C., Muñiz, I., Quintana, M., Simon, F., Castillo, B., de la Fuente, H., Widener, M., 2022. Short run "rebound effect" of COVID on the transport carbon footprint. Cities 131, 104039. https://doi.org/10.1016/j.cities.2022.104039.
Schwanen, T., 2021. Achieving just transitions to low-carbon urban mobility. Nature Energy 6 (7), 685–687. https://doi.org/10.1038/s41560-021-00856-z.
Sdoukopoulos, A., Pitsiava-Latinopoulou, M., Basbas, S., Papaioannou, P., 2019. Measuring progress towards transport sustainability through indicators: analysis and metrics of the main indicator initiatives. Transp. Res. D Transp. Environ. 67, 316–333. https://doi.org/10.1016/j.trd.2018.11.020.
Seto, K.C., Davis, S.J., Mitchell, R.B., Stokes, E.C., Unruh, G., Ürge-Vorsatz5, D., 2016. Carbon lock-in: types, causes, and policy implications. Annu. Rev. Environ. Resour. 41, 425–452.
Shafiei, E., Davidsdottir, B., Fazeli, R., Leaver, J., Stefansson, H., Asgeirsson, E.I., 2018. Macroeconomic effects of fiscal incentives to promote electric vehicles in Iceland: implications for government and consumer costs. Energy Policy 114, 431–443.
Shafiei, E., Davidsdottir, B., Leaver, J., Stefansson, H., Asgeirsson, E.I., 2017. Energy, economic, and mitigation cost implications of transition toward a carbon-neutral transport sector: a simulation-based comparison between hydrogen and electricity. J. Clean. Prod. 141, 237–247. https://doi.org/10.1016/j.jclepro.2016.09.064.
Shafiei, E., Davidsdottir, B., Stefansson, H., Asgeirsson, E.I., Fazeli, R., Gestsson, M.H., Leaver, J., 2019. Simulation-based appraisal of tax-induced electro-mobility promotion in Iceland and prospects for energy-economic development. Energy Policy 133, 110894. https://doi.org/10.1016/j.enpol.2019.110894.
Sherriff, G., Butler, D., Brown, P., 2022. 'The reduction of fuel poverty may be lost in the rush to decarbonise': six research risks at the intersection of fuel poverty, climate change and decarbonisation. People, Place Policy Online 1–20. https://usir.salford.ac.uk/id/eprint/63765.
Simpson, N.P., 2019. Accommodating landscape-scale shocks: lessons on transition from Cape Town and Puerto Rico. Geoforum 102, 226–229. https://doi.org/10.1016/j.geoforum.2018.12.005.
Skaar Viken, B., 2011. The birth of a system born to collapse: laissez-faire the Icelandic way. Eur. Political Sci. 10 (3), 312–323. https://doi.org/10.1057/eps.2011.27.
Smith, A., 2007. Moving outside or inside? Objectification and reflexivity in the governance of socio-technical systems. J. Environ. Plann. Policy Manage. 9 (3–4), 351–373. https://doi.org/10.1080/15239080701622873.
Sovacool, B.K., Kester, J., Noel, L., de Rubens, G.Z., 2019. Energy injustice and Nordic electric mobility: inequality, elitism, and externalities in the electrification of vehicle-to-grid (V2G) transport. Ecol. Econ. 157, 205–217.
Sovacool, B.K., Noel, L., Kester, J., de Rubens, G.Z., 2018. Reviewing Nordic transport challenges and climate policy priorities: expert perceptions of decarbonisation in Denmark, Finland, Iceland, Norway, Sweden. Energy 165, 532–542. https://doi.org/10.1016/j.energy.2018.09.110.
Statistics Iceland. (2022). *Household vehicles ownership by type of energy*. Retrieved from Statistics Iceland: https://www.statice.is/statistics/environment/transport/vehicles/.
Statistics Iceland. (2022). *Population by regions, sex and age 1 January 1998-2022*. Retrieved from Statistics Iceland: https://px.hagstofa.is/pxen/pxweb/en/Ibuar/Ibuar_mannfjoldi_2_byggdir_Byggdakjarnarhverfi/MAN03250.px/?rxid=304f5085-fa80-4e23-8b32-cdefb3d0e6a7.
Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Sörlin, S., 2015. Planetary boundaries: guiding human development on a changing planet. Science 347 (6223), 1259855.
Susur, E., Karakaya, E., 2022. A reflexive perspective for sustainability assumptions in transition studies. Environ. Innov. Soc. Transit. 39, 34–54. https://doi.org/10.1016/j.eist.2021.02.001.
The World Bank. (2022). *GDP per capita (current US$)*. Retrieved from The World Bank: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.
The World Bank, 2022b. Poverty and Shared Prospensity. World Bank Publications, Washington D.C.. https://doi.org/10.1596/978-1-4648-1893-6
Thorgeirsson, T., 2018. New Frontiers in the Euro Debate in Iceland. Prosperity Through Trade and Structural Reform. Stockholm, pp. 199–222.
Ulfarsson, G.F., Steinbrenner, A., Valsson, T., Kim, S., 2015. Urban household travel behavior in a time of economic crisis: changes in trip making and transit importance. J. Transp. Geogr. 49, 68–75. https://doi.org/10.1016/j.jtrangeo.2015.10.012.
Upham, P., Sovacool, B.K., Monyei, C.G., 2022. Energy and transport poverty amidst plenty: exploring just transition, lived experiences and policy implications in Iceland. Renew. Sustain. Energy Rev. 163, 112533 https://doi.org/10.1016/j.rser.2022.112533.
Valsson, T., 2003. Planning in Iceland: from the Settlement to Present Times. University of Iceland Press, Reykjavik.

Virág, D., Wiedenhofer, D., Baumgart, A., Matej, S., Krausmann, F., Min, J., Haberl, H., 2022. How much infrastructure is required to support decent mobility for all? An exploratory assessment. Ecol. Econ. 200, 107511 https://doi.org/10.1016/j.ecolecon.2022.107511.
Vogel, J., Steinberger, J.K., O'Neill, D.W., Lamb, W.F., Krishnakumar, J., 2021. Socio-economic conditions for satisfying human needs at low energy use: an international analysis of social provisioning. Glob. Environ. Chang. 69, 102287 https://doi.org/10.1016/j.gloenvcha.2021.102287.
Waas, T., Hugé, J., Block, T., Wright, T., Benitez-Capistros, F., Verbruggen, A., 2014. Sustainability assessment and indicators: tools in a decision-making strategy for sustainable development. Sustainability 6 (9), 5512–5534. https://doi.org/10.3390/su6095512.
WHO, 2018. Environmental Noise Guidelines For the European region. World Health Organization (WHO). ISBN 978 92 890 5356 3.
WHO, 2021. WHO Global Air Quality Guidelines. Wold Health Organization, Geneva.
WHO, 2022. Road Traffic Injuries. World Health Organization. Accessed at. https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries#:~:text=Road%20traffic%20injuries%20are%20the,result%20of%20road%20traffic%20crashes.
Wiedmann, T., Lenzen, M., Keyßer, L.T., Steinberger, J.K., 2020. Scientists' warning on affluence. Nat. Commun. 1–10. https://doi.org/10.1038/s41467-020-16941-y.
Zhang, R., 2021. Long-term pathways to deep decarbonization of the transport sector in the post-COVID world. Transp. Pol. (Oxf) 110, 28–36. https://doi.org/10.1016/j.tranpol.2021.05.018.