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Large-scale Projects and the Green Transition: Key Concepts and Outlook

IRS Leibniz Institute for Research on Society and Space

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1. Introduction

Large-scale projects, often referred to as megaprojects, have been criticized for being too costly, too complex, too slow, and too risky, among other issues (Flyvbjerg, 2017; Fainstein, 2008; Merrow, 2011, Zhai et al., 2009). Despite such critiques, not only are megaprojects becoming more common—they are also becoming increasingly ambitious (Söderlund, 2017). Megaprojects are back on the political agenda of states and international institutions, but in contrast to modernist megaprojects undertaken in the post-war era by centralized planning authorities, today's megaprojects tend to involve a host of non-state actors and to be characterized by a diffusion of authority, action, and responsibility (Schindler et al., 2019). As a consequence, projects of unprecedented scale and scope are being planned and implemented, leading Flyvbjerg (2014, p. 6) to argue that we have now entered the "tera era of trillion-dollar projects".

Large-scale projects have been studied by scholars from a range of disciplines over the past decades. First and foremost, a vast body of project management and business studies literature has analysed the managerial and organizational challenges associated with megaprojects (e.g., Flyvbjerg, 2014; 2017; Biesenthal et al., 2018; Söderlund et al., 2017.). A major focus of this body of literature is the question of how to improve the performance of future projects, particularly because existing schemes have often been associated with unexpected challenges and benefit shortfalls. Scholars from various disciplines have examined large-scale urban development projects as tools for urban renewal. A central issue is often the public discontent over project implementation and the forms of resistance that follow. Negative public attitudes have been explained in the literature as the results of democratic deficits when it comes to transparency and public participation, as well as lacking integration of projects in urban processes and planning systems (e.g., Majoor, 2008; Swyngedouw, Moulaert & Rodriguez, 2002; del Cerro Santamaria, 2013). Several scholars have also criticized large-scale urban development projects for accelerating gentrification processes in the name of modernization or sustainable development (e.g., Argüelles, Cole & Anguelovski, 2022; Tarazona Vento, 2017).

Söderlund et al (2017) argue that the question of how megaprojects contribute to solving major problems in society is one of the most pressing and critical issues in current megaproject management research. Given their enormous costs and the vast resources they consume, it seems sensible to ask what value these projects bring to society. This working paper focuses on projects whose value lie in their contribution to solving sustainability challenges. In particular, it reflects on large-scale projects that play a role in the 'green transition', i.e., in the process of societal development away from fossil fuel dependency and overconsumption of natural resources. Succeeding with this process will require an expansion of renewable energy (RE) sources and a widespread implementation of low-carbon technologies (Söderholm, 2020). Given their ability to contribute in the acceleration of energy and mobility transitions, large-scale "green" projects like wind farms, solar parks, and gigafactories for electric vehicles (EVs) have a vital role to play here. Many of these projects are seen by their promoters as imperative in the fight against global climate change, and investment in RE technologies is growing (IEA, 2022). Still, the implementation of large-scale RE projects is often characterized by land-use conflicts and other challenges. These will be explored in a later section of the paper.

Söderlund et al (2017, p. 6) note that megaprojects "oftentimes operate as institutional projects—spearheading the change of institutional frameworks as well as beliefs and norm systems". In view of this, the need to rapidly expand RE to decarbonize societies begs the question of what wider effects large-scale RE projects come with beside their direct contributions in energy and mobility transitions**.** This is a central topic of the paper, which is structured as follows: section two introduces the plethora of terms used to described large-scale projects. Being the most frequent term used, so-called "megaprojects" are then examined in more depth in section three. Section four introduces the green transition concept and provides a background on various large-scale RE technologies and how they have been approached in the scientific literature. It discusses the nature and significance of such projects, and reflects on their wider implications for local communities, governance and institutions. Particular attention is given to examining gigafactories for EV and battery manufacturing as a new kind of "green" megaproject. The fifth section provides a discussion and an outlook.

2. Large-scale projects: a multiplicity of terms

A multiplicity of terms has been used in the literature to refer to various types of large-scale projects. "Megaproject" appears to be the most common term, and a substantial body of literature has been devoted to elucidating various aspects of their design, implementation, and impact. Lehrer and Laidley (2008, p. 788) argue that the term "megaproject" has increasingly been employed as an analytical concept in the academic literature, and that "its meaning has expanded to include a variety of mixed-use large-scale developments". Other terms found in the literature are "major project", "large-scale urban development project", "flagship development project", or "prestige project". Leick (2015, p. 60) notes that "it is difficult to understand whether these terms are synonyms or whether they address different properties of various kinds of projects", and Lecroart and Palisse (2007, p. 6) point out that 'large-scale' is "a convenient term for designating a very wide range of realities".

Table 1. Examples of large-scale project definitions in the literature.

”Megaproject”, ”mega-project”, "mega project"	Altshuler & Luberoff, 2003; Brunet, 2021; Huning & Peters, 2003; Ibert, 2007; Fainstein, 2008; Lehrer & Laidley, 2008; Orueta & Fainstein, 2008; Peric & D'hondt, 2020; Priemus, 2010; Salet et al., 2013; Tarazona Vento, 2017
"Major project", "major public project"	Flyvbjerg, 2011; Klakegg & Haavaldsen, 2011; Brunet & Aubry, 2016
"Large-scale urban development projects", "Large-scale urban projects"	Swyngedouw et al., 2002; Lecroart & Palisse, 2007; Gualini & Majoor, 2007; Leick, 2015
"Flagship projects", "Flagship development projects"	Carrière & Demazière, 2002; Hult, 2015; Smyth, 1993
"Prestige projects"	Loftman & Nevin, 1995

3. Megaprojects

3.1. Megaproject definitions

Given that "megaproject" arguably is the most frequently used term in the literature, several authors have attempted to define what constitutes such a project**.** According to Flyvbjerg (2017, p. 2), megaprojects are "large-scale, complex ventures that typically cost US$1 billion or more, take many years to develop and build, involve multiple public and private stakeholders, are transformational, and impact millions of people". Fainstein (2008, p. 768) offers a looser definition, positing that "essentially it involves a costly scheme for development of a contiguous area, requiring new construction and/or substantial rehabilitation. Implementation may take several years and may be the responsibility of a single or multiple developers". She further notes that "mega projects always include a transformation of land uses" (ibid.). Zhai, Xin, and Cheng (2009, p. 99) argue that megaprojects are associated with "extreme complexity, substantial risks, long duration and extensive impact on the community, economy, technological development, and environment of the region or even the whole country". The ability of these kinds of projects to drastically alter environments is further stressed by Gellert and Lynch (2004, pp. 15–16), who define megaprojects broadly as "projects which transform landscapes rapidly, intentionally, and profoundly in very visible ways, and require coordinated applications of capital and state power".

As these definitions illustrate, megaprojects can be differentiated from other projects by the following factors:

- The amount of capital invested in them
- Their long duration and high risks
- The level of complexity inherent in their design and implementation
- The multiplicity of stakeholders involved
- The wide impacts that they have on places, systems, and communities

Merrow (2011, p. 12) adds that many megaprojects "end up being disappointing to their sponsors; a fewer number turn out to be destroyers of shareholder wealth; and a few are horrendous with respect to anything and everything involved—the investing companies, the local population and the environment." Indeed, because of their characteristics, 90 percent of megaprojects have problems like cost overruns and schedule delays (Wang, Fu & Fang, 2019). Still, Söderlund et al (2017, p. 6) argue that megaprojects "represent the major achievements by collectives to influence the progress and direction of society", and that "launching a megaproject is a way of getting things done—of creating dreams and high aspirations".

3.2. A brief history of megaprojects

In their study of more than half a century of megaprojects in the US, Altshuler and Luberoff (2003) present some distinct features associated with megaproject development of different eras. The categorizations are partly overlapping and can be applied to a European context as well, albeit with some variance in features and with a certain time delay. For example, industrial, economic and physical infrastructure of some European countries were severely affected by World War II, forcing them to prioritize recovery and reconstruction efforts.

1) The pre-1950s: this era saw rapid population growth and infrastructure investments, but the impacts of the Great Depression and World War II resulted in little support from higher levels of government for large-scale projects. Local governments very rarely imposed significant disruptions on existing districts. Instead, small projects spread widely across city neighborhoods were prioritized.

2) 1950 to late 1960s: known as 'the great mega-project era', this time period saw massive investment programs aimed at modernizing inner city neighborhoods and strengthening their economic positions. Unprecedented infusions of federal aid resulted in new roads, parking garages, and the construction of large, mono-functional brutalist buildings, often built with little consideration for the environment and for existing spatial uses.

3) Mid-1960s to early 1970s: the 'era of transition'. As movements and protests for civil rights, environmental protection and citizen participation grew, attempts were made to implement less one-sided projects. Governments adopted rules that greatly constrained disruptive public

investment. Brownfield regeneration—the re-use of vacant land from obsolete and often industrial sites—was emphasized.

4) Mid-1970s to now: the era of “do no harm”, in which interest in megaprojects started to grow again, but with more questioning of the social, economic, and environmental impacts of each project. An increase in less disruptive projects, such as convention centers, sports arenas and airport terminal improvements, can be observed.

Majoor (2008) points out that although downtown waterfronts and brownfields are still popular locations for large-scale development projects, the spreading of social and economic activities across metropolitan regions has made locations on the fringes of cities or even outside traditional urban cores grow in popularity, especially when such sites are well connected to transportation networks.

3.3. What drives megaproject implementation?

As we have seen, megaprojects tend to be associated with schedule and cost-overruns, as well as serious benefit shortfalls, but they nevertheless continue to be promoted and built. Flyvbjerg, Bruzelius and Rothengatter (2003) have referred to this as the ‘megaproject paradox’, and in an often-cited paper, Flyvbjerg (2014) offers an answer to the question of why megaprojects keep being undertaken despite the now widespread knowledge of their shortfalls. He argues that megaproject development can be motivated by four ‘sublimes’—technological, political, aesthetic, and economic—which drive the promotion of new projects despite their often poor performance.

The term ‘technological sublime’ was introduced to the study of megaprojects by Frick (2008) and describes the excitement engineers and technologists get from pushing the boundaries in terms of what technology can do, manifested in projects with ‘longest–tallest–fastest’ aspirations. Next, the ‘political sublime’ refers to the personal satisfaction politicians get from building monuments to themselves and their causes, lending them an air of proactiveness and generating the kind of visibility with the public and the media that helps them get re-elected. Third, the ‘aesthetic sublime’ refers to the pleasure designers and others who enjoy good design get from building, using, and beholding something very large that is also iconic and beautifully designed, such as the Golden Gate Bridge in San Francisco. Lastly, the ‘economic sublime’ is the prestige businesspeople and trade unions get from making large profits and generating jobs off megaprojects. Given their vast budgets, there is enough money to cover the costs for contractors, architects, construction and transportation workers, bankers, landowners, lawyers, and developers.

Schindler, Fadaee and Brockington (2019, p. 6) write that after the 2008 financial crisis, the US Department of the Treasury set off a generous fiscal stimulus package aimed at calming investors and bolstering markets that resulted in “a decade of cheap capital that has often been funneled into megaprojects”. Indeed, the economic drivers behind megaproject implementation should not be glossed over. Bracking (2016, cited in Schindler et al., 2019) argues that the different stages of megaproject implementation, from their construction to the contracts to run and maintain them, provide revenue streams that can then be financialized. This leads Schindler et al (2019, p. 6) to argue that “megaprojects provide a means by which the ‘great predators’ of capitalism extract huge revenues from states”.

Writing about megaprojects in the Global South from a sociological perspective, Gellert and Lynch (2004) argue that modernization ideology, with its faith in technology and belief in domination of nature, produces a specific bias towards projects of a larger scale. The institutional logic of international lending institutions favors large loans, “even in the face of concerns about the environment, displacement, human rights, or even the utility of a project” (ibid., p. 22). Since these institutions only support projects amenable to international bidding, projects are only funded if they are big enough to catch the interest of multinational construction firms.

3.4. Megaproject categorizations

The literature shows that there is a plethora of contemporary large-scale projects being designed and implemented, leading various scholars to present analytical categories to divide them into. Huning and Peters (2003) have suggested four, partly overlapping, heterogenous categories: major events, flagship image projects, urban renaissance projects and large-scale infrastructure projects.

1) Examples of major events include the Olympic Games, world exhibitions, or the European Capital of Culture. As a general rule, these projects have a lead time of many years and are used as catalysts for a large number of infrastructure or other development measures. They are often co-financed by the federal or state level, and their effects can be seen and felt long after the actual event period has passed. Examples of major events that have been covered in the literature include the EXPO 2000 in Hannover (Ibert, 2007) and the 1966 FIFA World Cup in England (Gillett & Tennett, 2017).

2) Flagship image projects are intended as unique selling propositions to raise the profile of an entire city/region and/or a company. They can be developed by municipalities, private investors or in public-private partnerships. Examples that have been covered in the literature include Autostadt Wolfsburg (Tessin, 2003), Milan's Porta Nuova and CityLife (Conte & Anselmi, 2022), and the City of Sciences in Valencia (Tarazona Vento, 2017).

3) Urban renaissance projects refers to large-scale development projects that aim at the targeted upgrading of certain parts of a city, often industrial sites and other locations close to the city center. Commercial uses are usually given a much higher priority than residential uses in these projects. As a result, rather than producing integrated neighborhoods, they tend to give rise to tourist bubbles or new office locations surrounded by gentrified residential islands. A large number of case studies of such projects have been carried out in the last decades, many of which have examined new waterfronts of cities like London (Hinsley & Malone, 1996; Florio & Brownill, 2000)**,** Toronto (Lehrer & Laidley, 2008), Copenhagen (Desfor & Jørgensen, 2004) and Belgrade (Peric & D'hondt, 2020).

4) Large-scale infrastructure projects include airports, railway stations, tunnels, bridges, and other transport projects, but also technology parks. These projects—which can also be categorized as flagship image projects or urban renaissance projects—have an investment volume of several hundred million to several billion euros and are mainly financed by the public sector at the state or federal level. Examples of large-scale infrastructure projects analyzed in the literature include the Euralille urban quarter project (Simons, 2003), Lisbon Airport (Huber, 2014) and the train station renewal project Stuttgart 21 (Nagel & Satoh, 2019; Novy & Peters, 2012; Schmidt-Thomé & Mäntysalo, 2014)**.** Studies often question the public benefit and political legitimacy of these schemes, given that they are usually funded by public taxes.

Gellert and Lynch (2004) also differentiate between four types of megaprojects, distinguished by their function (although they often occur in combination): (i) infrastructure (e.g., ports, railroads, urban water and sewer systems); (ii) extraction (e.g., minerals, oil, and gas); (iii) production (e.g., industrial tree plantations, export processing zones, and manufacturing parks); and (iv) consumption (e.g., massive tourist installations, malls, theme parks, and real estate developments).

Writing a few years later, Diaz Orueta and Fainstein (2008, p. 761) categorize the “new generation of mega-projects” as belonging to one or more of the following categories: (i) regeneration of waterfronts; (ii) recovery of old manufacturing and warehouse zones; (iii) construction of new transport infrastructures or the extension of existing ones; and (iv) renovation of historic city districts, usually to meet the special consumer demands of middle- and upper-class sectors. The authors note that the term “new” should not necessarily be seen as describing a different type of project compared to earlier ones; rather, they intend it to have a neutral meaning, i.e., recent. Still, an important distinctive element of this generation of projects is the introduction of new methods of financing in which the public and private sectors collaborate to a greater extent. Often developed in public-private partnerships, these projects reflect an agenda in which the neoliberal state promotes new, decentralized forms of governance and market-led development. In this context, state actors facilitate and encourage big urban projects through the creation of the necessary legal, political, and economic frameworks (Brenner & Theodore, 2004). These projects are frequently mixed-use, and “cater to the needs of office-based businesses and tourism and leisure services” (Diaz Orueta & Fainstein, p. 760).

Lehrer and Laidley (2008) take a similar point of view, arguing that while the ‘old’ megaprojects had a single purpose, such as energy production (hydropower dams) or the transport of goods and people (highways), the ‘new’ mixed-use megaprojects take the form of vast complexes that include housing as well as retail and office spaces. They are typically surrounded by publicly accessible parks and supported by community and cultural facilities. In addition to being mixed-use, projects involve “a variety of financing techniques and a combination of public- and private-sector initiators” who are motivated by the goal of elevating the position of city-regions within a competitive global system (ibid., p. 789). This ambition follows from a development in which “cities and city-regions increasingly function as semi-independent economic entities in international economic networks” (Spaans, Trip & van der Wouden, 2013, p. 30). Consequently, European cities regularly compete for EU grants, for national and international investment, and for hosting prestigious international events, leading to an interweaving of urban planning, economic policy and city marketing (Thornley & Newman, 1996). Accordingly, megaprojects are often motivated with the argument that they will help integrate cities into the international property and financial market, or into global socio-cultural networks (Lehrer & Laidley, 2008). This has mainly been a strategy of larger cities, with the consequence that most of the scientific literature on large-scale urban projects have focused on larger cities or metropolitan areas, while secondary, medium-sized and small cities are rarely covered (Leick, 2015).

As we have seen, large-scale projects or megaprojects come in many different shapes and sizes. While some authors differentiate them by their scale, cost, or level of complexity, others categorize them according to their function. There are several reasons why megaprojects continue to be promoted despite their various shortfalls. A particularly strong reason appears to be the fact that the multiple stages involved in their design, implementation, and maintenance offer lucrative ventures for investors. The prospects of elevating cities and regions further make megaprojects attractive to public stakeholders. Some schemes, like flagship image projects and urban renaissance projects, involve mainly local or regional public actors, while major events and infrastructure projects include stakeholders at higher levels of government. Their impacts are also often felt at scales that reach beyond the local or regional.

What becomes clear when examining the literature is that megaproject development is closely linked to economic development and to the idiosyncrasies of global markets. This has given rise to new models of financialization and to private sector actors having more prominent positions in project design and implementation, resulting in a diffusion of responsibilities among stakeholders and a need for greater collaboration across governance levels and sectors. These developments have made the megaprojects of the 21st century more complex than their predecessors, and pose challenges for governments at all levels. This is certainly true for the implementation of large-scale RE projects in the context of the green transition, which will be discussed in more detail in the next section.

4. Large-scale projects and the green transition

4.1. The green transition

Extreme weather events and reductions in global food supply are some of the negative effects of global climate change that are already occurring. Continued greenhouse gas emissions increase the likelihood of severe, pervasive, and irreversible effects on people and ecosystems—risks that can only be limited through substantial and sustained reductions in GHG emissions, coupled with adaptation measures (IPCC, 2014). Since greenhouse gas emissions and environmental degradation are largely caused by human behavior, they can be limited by changes in production, consumption, and waste management (Pawlik & Steg, 2013; IPCC, 2014). Studies of such changes can often be found within transitions literature, which studies the drivers, mechanisms, and dynamics behind shifts in large and complex sociotechnical systems (Geels, 2002; Markard, Raven, & Truffer, 2012; Smith, Sterling, & Berkhout, 2005). These systems involve infrastructures, institutional and governance models, market structures and consumer patterns (Smith et al., 2005). This means that achieving, for example, a change to carbon-free energy technologies requires not only technological progress, but also economic and societal adjustment in the form of infrastructure development, novel business models, changed consumer behavior, and amendments to legal frameworks (Söderholm, 2020).

The term ‘green transition’ has been used by researchers and decision-makers to describe a shift to more sustainable societies that are not dependent on fossil fuels and overconsumption of natural resources[1]. It encapsulates wide-ranging, multi-dimensional changes necessary to establish a ‘green economy’—one that not only sees a growth in income and employment but is also “driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services” (UNEP, 2011, p. 2). The green transition is pursued in different sectors and industries to varying degrees, including transport, housing, agriculture and energy (Coenen, Benneworth & Truffer, 2012).

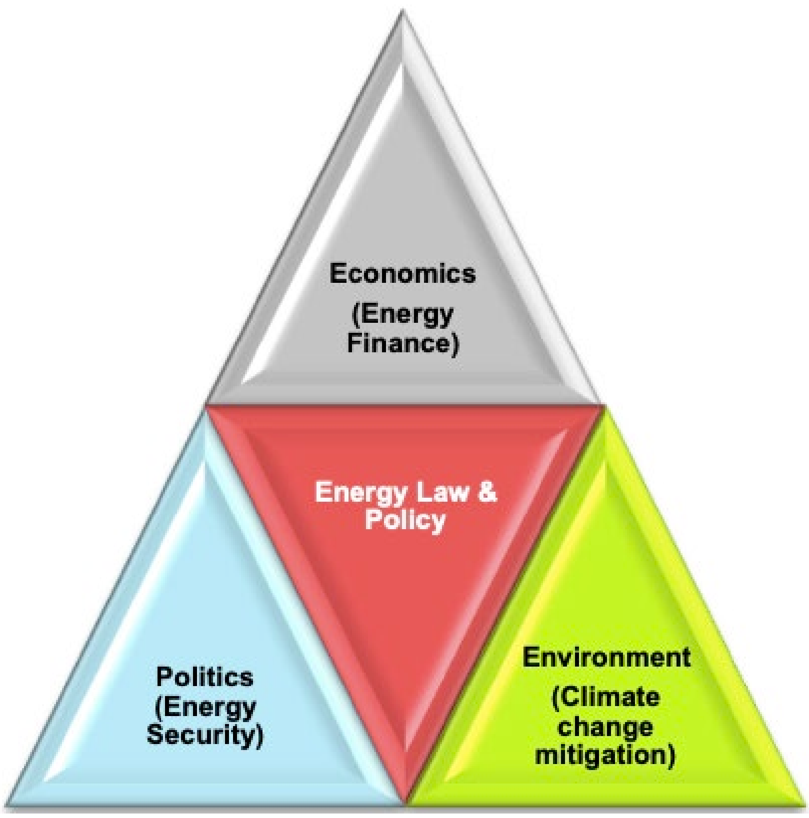
Energy, whether in the form of electricity production, transport, or heating, is a central issue in the green transition (Potts, Niewiadomski & Prager, 2019). Achieving energy transitions is imperative to succeeding with transitions in other fields such as transport, and is consequently a focal point in transitions literature. Broadly speaking, energy transitions refer to “processes that entails changes from one form, style, state, place or scale of energy system to another” (Edomah, Bazilian & Sovacool, 2020, p. 1). In a green economy context, this implies a shift from an energy production system relying on fossil fuels to one based on renewable energy sources, combined with high levels of energy efficiency. Energy system changes occur on different scales among stakeholders, sectors, and within different government levels (municipal, sub-national, national, and international) (Child & Breyer, 2017; Edomah et al., 2020). Furthermore, the scope and speed at which they take place are influenced by social dimensions such as knowledge, motivations, and contextual factors within different energy geographies (Steg, Perlaviciute & van der Werff, 2015).

[1] The term ‘transformation’ is often used interchangeably with ’transition’ to examine pathways for desired environmental and societal change (Hölscher, Wittmayer, & Loorbach, 2018). Both transitions and transformations include processes of innovation (e.g. institutional, social, technological, economic), collaboration, learning, and knowledge integration (ibid., 2018).

York and Bell (2019) point to the need to distinguish between energy *transitions* and mere energy *additions*. Historically, when a new energy source grew rapidly, the older energy source still continued to grow, leading to an expansion in the overall amount of energy produced rather than a complete switch of sources. While renewable energy will likely provide a growing share of the global energy supply, the authors argue that a transition away from fossil fuel dependency cannot just rely on a growth in alternative sources. Instead, achieving a sustained change in energy use patterns will likely require a multi-faceted approach that combines targeted policies and citizen-driven change (Edomah et al., 2020).

Potts et al (2019) point out that the literature has mainly focused on technical and innovation-oriented aspects of energy transitions. Less regard has been paid to social and political dimensions, even though transitions are "deeply coupled with economic growth" and "inherently socio-political in nature" (ibid., p. 364). Indeed, energy transitions draw attention to the sometimes conflicting nature of political, economic, and environmental goals. This phenomenon has been referred to as the "energy trilemma" and constitutes a key problem for governments (Heffron, McCauley and Sovacool, 2015). The energy trilemma is visualized as a triangle with energy law and policy at the center and the issues of economics, politics, and environment at the three vertices. Each issue has many sub-issues that try to pull legislation and policy in their direction. In an ideal situation, effective and efficient energy law and policy would ensure balance between the three and deliver the best outcome to society. In reality, however, the energy agenda is often dominated by economic issues to the detriment of the other two. This means, for example, that energy affordability and low-cost solutions often dominate discussion on what energy source should be used, which in turn leads to a favoring of the continued use of low-cost fossil fuel energy sources (Heffron & McCauley, 2017). Consequently, Heffron et al (2015) call for a critical evaluation of the implications of energy policy in order to ensure a just and equitable balance between the three dimensions.

Figure 1. The Energy Law and Policy Triangle—The Energy Trilemma, with examples of issues in brackets (Heffron et al., 2015).



4.2. Large-scale renewable energy projects

There is a significant body of literature devoted to examining various aspects of large-scale RE projects. The contentious issue of social acceptance of wind power projects is well-researched (e.g., Bout et al., 2021; Gross, 2007; Ellis & Ferraro, 2016; Enevoldsen & Sovacool, 2016; Wilson & Dyke, 2016), as are the attitudes to solar energy projects—albeit to a lesser extent (e.g., Carlisle et al., 2015; Cousse, 2021). Because of their de-facto transformation of landscapes, large-scale RE schemes sometimes lead to land-use conflicts between project promoters, governments, and indigenous people (Avila, 2018; Cambou, 2020; Kelly, 2021; Talamayan, 2021), but projects also frequently face opposition from NGOs, from social and environmental movements, and from people who oppose large-scale RE development in their local community. Interestingly, large-scale RE projects have generally not been a topic of research in megaproject literature, even though many large-scale RE projects share the typical characteristics of megaprojects: a high amount of capital invested; long duration and high risks; a high level of complexity; a multiplicity of stakeholders involved (in both financing and implementation); and wide impacts on places, systems, and communities.

Unlike other RE technologies that have been largely overlooked in the megaproject literature, hydropower has been addressed in several studies (Ansar et al., 2014; Gellert & Lynch, 2004; Gutierrez et al., 2019; Huda, 2022). These studies typically identify environmental and human rights issues brought on by the construction of large dams. Most hydropower dams in the Global North were built before 1975, after which development came to a halt due to negative social and environmental impacts (Moran et al., 2018). However, the Global South has seen an expansion of even larger dams since the 1970s, particularly in river basins known for their rich biodiversity, such as the Amazon, the Congo, and the Mekong (ibid.). Hydropower is the largest and one of the oldest renewable sources of electricity worldwide, accounting for up to 71% of this supply as of 2016 (ibid.). Between 1950 and 2019, the number of large dams globally grew from 5000 to over 59 000 (Gutierrez et al., 2019).

Hydropower is increasingly promoted by governments and industry actors as being central to renewable energy transitions. This has led to a rapid development of small-scale projects and a resurgence of large-scale projects (Gutierrez et al., 2019). However, hydropower projects have been criticized for causing deforestation (Stickler et al., 2013), large reservoir emissions (Deemer et al., 2016), and for threatening terrestrial and freshwater biodiversity (Benchimol & Peres, 2015). Large-scale dams have also been denounced on the basis of the many negative social impacts that they cause, including displacements of large numbers of people (Gellert & Lynch, 2004). Gutierrez et al (2019) point out that since 1950, the construction of hydropower dams has catalyzed the displacement of an estimated 40-80 million people. Cost and schedule estimates of contemporary hydropower projects are often severely and systematically flawed, leading researchers to urge policymakers in developing countries to prioritize developing agile, small-scale alternatives over large dams (Ansar et al., 2014).

As previously mentioned, social acceptance to new projects is a common topic in literature on RE technologies. A significant body of literature has been devoted to assessing the relevance of the concept known as Not-In-My-Backyard (NIMBY) for explaining opposition to new projects—particularly in the case of wind power expansion (e.g., Wolsink, 2000; van der Horst, 2007; Haggett, 2011). The acronym emerged in the 1980s and is a hypothesis suggesting that people tend to be supportive of RE projects in general but are likely to oppose specific project plans in their local area. In the recent decade, NIMBYism has come to be seen as ”an inaccurate and unhelpful way of characterizing opposition to siting” (Burningham, Barnett & Walker, 2015, p. 247), and scholars have sought to provide more sophisticated understandings of factors that contribute to public acceptance or resistance to RE technologies. These include emotional attachment to certain places (Devine-Wright, 2009), perceived visual quality of projects (Wolsink, 2000), and political, social, and environmental values (Kempton et al., 2005). Various benefit-sharing mechanisms (e.g., local ownership models, taxation and community funds) can also have a positive influence on social acceptance (Bauwens et al., 2016; Curtin, McInerney & Johannsdottir, 2018; Ejdemo & Söderholm, 2015).

Additional factors that influence wind power deployment include governance settings (Biehl, Köppel & Grimm, 2021; Barr Lebo, 2019) and policy instruments. Policy instruments can be divided into two main categories: public support schemes and land-use policies (Lauf et al., 2020). Public support schemes such as feed-in tariffs have been shown to significantly influence the profitability of wind power deployment (Lauf et al., 2020), and scholars have closely examined the impact of such schemes at the the global scale (Carley et al., 2017), in the USA and Europe (Alagappan, Orans, & Woo, 2011; Delmas & Montes-Sancho, 2011; Jenner, Groba & Indvik, 2012; Nelson, 2008; Shrimali, Lynes & Indvik, 2015), and in the BRIC countries, i.e. Brazil, Russian, India, China and South Africa (Bodas Freitas, Dantas & Iizuka, 2012). Land-use policies determine the sites at which wind turbines can be installed, how large they can be, and the hours at which they are allowed to operate. They are specified in national and regional planning and environmental permitting regulations and include priority areas, protected areas, et cetera. Several qualitative case studies have examined the importance of national and regional permitting and planning systems on wind power expansion in countries such as Poland (Hajto et al., 2017), the USA (Köppel et al., 2014), Germany (ibid.; Masurowski, Drechsler & Frank, 2016), the Nordic countries (Larsson & Emmelin, 2016; Larsson, Emmelin & Vindelstam, 2014; Pettersson et al., 2010), and various regions of the UK (Aitken, McDonald & Strachan, 2008; Cowell, 2010). These studies illustrate how land-use policies differ between different regions and countries, and point to such policies as a factor that may influence the spatial heterogeneity of wind power deployment. This argument has been further supported in a quantitative study by Lauf et al (2020).

There is a rapidly growing interest in (green) hydrogen globally. Hydrogen is not an energy source but a versatile energy carrier that can be used as a component or catalyst in industrial processes like ammonia production, oil refining and methanol production (FCHEA, n.d.). The majority of hydrogen produced today stems from natural gas, coal, or oil, while so-called 'green' hydrogen produced from renewable energy via electrolysers will need dedicated industrial policies to grow (IRENA, n.d.). Hydrogen plays a key role in the EU Green Deal and in the REPowerEU plan (European Commission, 2023), and countries worldwide have either developed or are developing hydrogen strategies (Stapczynski & Lee, 2022). A large number of European countries have also joined forces to promote large-scale hydrogen projects that can contribute to reaching climate targets and support sustainable industrial jobs (BMWK, 2021). Germany alone has announced an investment of €8 billion in 62 large-scale hydrogen projects to help decarbonize its industry—including electrolysers and pipeline infrastructure (Kurmayer, 2021). Since green hydrogen technology is still in its early stages, the academic literature on the subject is so far mostly devoted to analyzing technological details, technology transfer, and policy recommendations for its expansion (Rabiee, Keane & Soroudi, 2021; Benalcazar & Komorowska, 2022; Nurdiawati & Urban, 2022; Sadik-Zada, 2021; Li, Shi & Phoumin, 2022; Öhman et al., 2022).

4.3. Gigafactories: a new kind of "green" megaproject?

Gigafactories arguably represent a new kind of megaprojects that combines elements of the 'old' and 'new' types of projects (Lehrer & Laidley, 2008). 'Giga' relates to the production capacity of the factories, which is typically expressed in gigawatt hours (GWh). Like the older generation of projects in the 20th century, gigafactories are single purpose schemes, typically designed to produce EVs or battery cells for EVs at a rapid and large scale. They can be labeled as megaprojects for several reasons. First of all, they are huge constructions that require very large sites to be built and therefore result in significant transformations of landscapes. Second, they are characterized by complexity in their design and with regards to their dependency of well-functioning supply chains of minerals (lithium, cobalt, nickel, graphite, and manganese) and of specialist parts such as semiconductors. The manufacturing itself is complex as well, as the production of lithium-ion batteries comes with specific environmental requirements that entail constant air filtering and a strict regulation of humidity levels to keep rooms dry and clean (Evans, 2022). Third, they are massively expensive schemes, costing up to several billions of dollars (Steitz & Schimroszik, 2021). However, because of high levels of automatization and digitalization in the planning and construction processes, they do not need several decades to be built (cf. Flyvbjerg, 2017), but can be completed in a few years. Fourth, they have wide impacts on the economies and environments of the communities in which they are built. Indeed, like the 'new' generation of megaprojects of the first decade of the 21st century, the factories tend to be surrounded by office and retail spaces and may ignite plans for further urban development of surrounding areas by local or regional administrations. For example, the establishment of Tesla's gigafactory in Grünheide in Brandenburg has resulted in the development of an ambitious planning concept for residential and commercial areas by the states of Berlin and Brandenburg and 22 cities and municipalities in the factory's vicinity (Land Brandenburg, n.d.).

Gigafactories bear a strong resemblance to other contemporary megaprojects in their decentralized nature with regards to financing and to the actors involved in their implementation (Schindler et al., 2019). They are designed and built by private sector actors like vehicle manufacturers or battery cell producers, but their implementation often involves the support and cooperation of actors at multiple levels of government. Since gigafactories have become a major driver of foreign direct investment (FDI), and since their presence can boost associated industries and supply chains, there is often a strong national interest in being chosen by companies seeking locations for their factories. Tax breaks, subsidies, and industrial strategies are some of the tools used by countries to attract investors and strengthen the battery value chain (Whiteaker, 2022).

At the EU level, the European Commission (EC) has a strategic interest in expanding the European battery value chain due to its market value potential, its importance for a competitive industry, and its role in the transition to renewable energy (González & de Haan, 2020). Consequently, the EC—and some European countries like France and Germany—are shifting from an industrial policy based on open market and direct competition to one that allows for greater government intervention in supporting business investments (ibid.). In 2017, the EC launched the European Battery Alliance with the objective to build a sustainable and competitive European battery industry (European Commission, 2022a), and in 2020, the European Investment Bank (EIB) granted Umicore and LG Chem €125 million and €480 million for the construction of battery production facilities in Poland. Northvolt was granted €350 million for the construction of a battery gigafactory in Sweden (ibid.). State aid is also being used to strengthen European battery production: in 2019, the EC approved €3.2 billion of state aid in seven countries to support projects along the entire battery value chain. The funding was granted within the Important Projects of Common European Interest (IPCEI) framework (ibid.). More efforts will likely be needed in the near future to strengthen Europe as an attractive production location, particularly as the signing of the Inflation Reduction Act into US law by President Biden in August 2022 has created a strong incentive for manufacturers to set up or move (parts of) their businesses to the US (Goldthau & Neuhoff, 2022).

The fact that gigafactories not only bring employment opportunities in the factories themselves but may also generate economic ripple effects on communities sparks excitement among local and regional governments (Lindstedt, 2021; Poppendieck, 2022). The fear of losing such opportunities arguably puts pressure on politicians and public servants to make project implementation as smooth as possible. Indeed, before the construction of Tesla's gigafactory in Grünheide had begun, representatives from the state, district, and municipal government joined forces with Tesla in a multi-level coalition known as "Task Force Tesla" with the aim to remove bureaucratic hurdles and speed up the approval process (Kersting & Neuerer, 2022).

Echoing Lehrer and Laidley (2008), gigafactories have the potential to elevate a city-region's brand by giving it an aura of innovation and prosperity. Gigafactories can thus be considered a kind of flagship image projects (Huning & Peters, 2003) that arguably touch upon at least three of Flyvbjerg's (2014) sublimes promoting their implementation: the technological, political, and economic. First of all, the 'longest–tallest–fastest' aspirations of the technological sublime are reflected in news reports of how rapidly gigafactories are being built, how fast they can produce new cars or batteries, and in the descriptions of "cutting edge" technology involved in the manufacturing processes (e.g., Hoge, 2016; Hull, 2022). Second, the political sublime can be seen in the excitement local politicians express over the fact that an investor has chosen their particular community for a new gigafactory, preferably adding that they themselves had something to do with the location decision (e.g., Lüdecke, 2022). This is closely related to the third, economic sublime, as gigafactories not only bring profits to investors but promise the generation of new jobs in the factories themselves, among subcontractors, and in adjacent new business establishments. This argument is likely to be particularly appealing for structurally weak regions in dire need of economic upswing and population growth.

An additional factor associated with gigafactories that adds to the political sublime is the wish by businesses and politicians to be seen as pioneers in the fight against climate change. When Tesla was in the process of building its new gigafactory in Grünheide, the company proclaimed that it is their mission to speed up "the global energy and transportation transition that will be instrumental in combating dangerous climate change" (Tesla, 2021). Thus, the narrative was not in firsthand centered on economic growth or private profit but justified by a climate mitigation narrative. This narrative has been echoed by the state of Brandenburg, who describes the Tesla factory as a project that will contribute to the state's journey towards becoming a pioneer in the German energy and mobility transition (Land Brandenburg, 2022). This is a somewhat peculiar ambition considering that Brandenburg is one of a handful federal states in Germany that still has not developed a climate change act with legally-binding reductions for greenhouse gas emissions (Eckersley et al., 2021).

Despite being promoted for their contribution in the fight against global climate change, it is debatable whether gigafactories can be labelled as 'green' or sustainable. On the one hand, they contribute to the decarbonization of transport by putting EVs and lithium-ion batteries on the market, thereby facilitating the transition away from internal combustion engines run on fossil fuels. Lithium-ion batteries also play an increasingly important role in stationary renewable energy storage solutions (Chen et al., 2020). At the same time, the processes of manufacturing EVs and their batteries undeniably demand immense amounts of energy, which needs to come from renewable sources to ensure that the vehicles and batteries produced have low-carbon footprints. While some investors have assured that their new gigafactories will be run primarily or completely on renewable energy (Amelang, 2022; EIB, 2020), the manufacturing processes also require big quantities of different kinds of precious minerals. Indeed, the World Bank estimates that the demand for lithium, cobalt and graphite could grow by nearly 500 percent by 2050, driven almost entirely by the production of EV batteries (Hund et al., 2020). Large-scale mining of these minerals in countries like Argentina, Chile, and the Democratic Republic of Congo has been linked to negative environmental impacts such as water scarcity and pollution, and to human rights violations in the form of community abuses, dangerous mining conditions and child labor (González & de Haan, 2020). Furthermore, constructing the factories often require the clearing of large forest areas, and may come with other environmental impacts such as water scarcity. This begs the question of how sustainable and just a mobility transition based on the widespread uptake of EVs really is.

Perhaps because they are a relatively new phenomenon, gigafactories have been the subject of relatively little scientific research. Most existing research have examined the EV or battery firms behind the gigafactories rather than the factories themselves and their wider implications. Examples of topics include business models (e.g., Cheong et al., 2016; Nieuwenhuis, 2018), valuation (e.g., Liu, 2021), and firms' influence on national automotive industries (e.g., Clausen & Oltenau, 2020). A few studies apply more of a factory-focus, analyzing location decisions and manufacturing processes (e.g., Asaba et al., 2022; Cooke, 2020; Breul & Neise, 2020); issues of territoriality and spatial planning (e.g., Eichenauer & Ulrich, 2022); and the environmental effects of factory settlements (e.g., Leibenath & Kurth, 2021).

5. Discussion and outlook

The need to address global climate change makes governments and international institutions advocate for rapid expansion of RE and promote investment in projects that can improve energy storage and help decarbonize transport and heavy industries. The European Commission recently announced a third call for large-scale project funding through its Innovation Fund, offering a total of €3 billion to projects within clean tech manufacturing, industry electrification, hydrogen, and general decarbonization (European Commission, 2022b). At the same time, large-scale RE implementation tends to be fraught with issues. Land-use conflicts, environmental impacts, and human rights violations evoke crucial questions about legitimacy, justice and the right to resources, and draw attention to the diverging interests, values and prospects of future that materialize in the context of the green transition (Bradley & Herdén, 2014).

Large-scale RE projects bring the energy trilemma (Heffron et al., 2015) to the fore. Their size, investment volumes and vast (positive and negative) impacts on local communities push conflicting economic, political, and environmental goals into the public light. This puts considerable pressure on governments who need to navigate conflicting goals and formulate policies with the best possible societal outcomes. With climate change being a massive problem, it follows that, almost normatively, decision-makers would argue for a massive solution. The cost, complexity and sheer size of large-scale RE projects arguably signal that someone is addressing this challenge head-on.

Recently, the need to accelerate energy transitions has prompted discussions within the EU on lowering regulatory barriers for the mining of critical raw materials in Europe, as lengthy environmental permitting procedures are halting production starts in some regions (Fleming, Hancock & Wise, 2022). In some countries, government advisory bodies have suggested a speeding up of permitting procedures in order to facilitate the establishment of large-scale RE projects (Nationaler Normenkontrollrat, 2021; SOU 2022:33). The suggestions echo calls from industry actors who wish for smoother project implementation without bureaucratic hurdles causing “unnecessary delays” (Tesla, 2021).

These developments and other examples point to a possible trajectory in which the goal of mitigating climate change might be gaining dominance over other issues in the energy trilemma, such as local environmental protection. A contributing factor is arguably that there is more profit to be made in climate mitigation and clean tech innovation than in nature conservation. Still, a question for future research concerns what consequences this potential shift has on governance and institutions, and what role large-scale RE projects play in it.

Another topic of future research is the impact that large-scale RE projects may have on disadvantaged regions and communities. Gigafactories are particularly interesting in this regard, since they come with unprecedented promises of job opportunities and economic ripple effects. There is also a large national interest in gigafactories as drivers of foreign direct investment. Still, the establishment of large-scale industries in small or disadvantaged municipalities puts pressure on electricity and water supplies, infrastructure, and local welfare and housing systems. A question for further scrutiny therefore concerns what roles different government levels and other stakeholders assume in ensuring that electricity demands are met, that infrastructure is appropriately expanded, and that sufficient labor is mobilized for these settlements to be successful.

Sometimes, firms choose to locate their factories in remotely located municipalities characterized by depopulation, who face the added challenge of attracting labor willing to set up permanent homes and pay taxes in the local community rather than commute from other towns. Such municipalities often suffer from staff shortages within several important professions like nurses, teachers and social workers, and tend to have a very limited range of restaurants and recreational activities. At the same time, gigafactories can function as flagship image projects that catalyse new business ideas and elevate a municipality's image (Lindstedt, 2021). Innovation and entrepreneurship aside, a question for future research is also how—if at all—gigafactories affect local sustainability action. Given their green image, their presence in local communities may give local governments an incentive to improve their sustainability work and benchmark their municipalities not only as innovative and prosperous but also as frontrunners in the field of climate action.

Large-scale RE projects have effects that reach beyond the localities in which they are implemented. Consequently, they bring forward issues of scale as governments at different levels not only have different responsibilities but may also have conflicting interests. At the same time, achieving a green transition is contingent on a rapid expansion of RE technology. This will likely require targeted policies, regulatory amendments to permitting procedures, and coordinated governance between the private sector, states, regions and municipalities. A key question for the green transition will therefore likely be how governments at different levels handle resource and value conflicts, coordinate action, and divide responsibilities between themselves. Large-scale RE projects arguably provide a favorable backdrop for studying this.

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