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Low-carbon lock-in? Exploring transformative innovation policy and offshore wind energy pathways in the Netherlands

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ABSTRACT

A new era of transformative and mission-oriented innovation policy has arisen due to the urgency of grand societal challenges, such as climate change. This new era requires a massive restructuring of societies, industries and consumption and will depend on, in part, new technologies and a high degree of coordination between the industry, civil society and government. These new forms of innovation policy may seriously alter classic innovation dynamics. This is indeed the case in offshore wind, in which a specific institutional architecture has led to a rapidly formed dominant design that emerged early in the technology's development. Radical experimentation, normally expected at the beginning of technological development, only began to emerge after 20 years of diffusion. This trend reverses classic innovation pathways. This paper empirically demonstrates this reversed innovation trend and then proposes a new innovation dynamic founded in a new era of grand societal challenges. It then proceeds to illustrate how The Netherlands has promoted and embedded a rapidly formed dominant design through an analysis of its offshore wind innovation system based on 31 interviews. It concludes that well-positioned incumbents and a specific innovation system architecture have created this trend, a notion applicable to a broader socio-technical system context. A rapidly formed dominant design and quick diffusion are critical to ensuring countries meet their climate pledges, but may risk early lock-in if there is no room for experimentation. We propose that governments ensure sufficient attention to variety and experimentation in innovation systems while maintaining a focus on rapid diffusion.

1. Introduction

Urgency of grand societal challenges, such as climate change, requires a massive restructuring of societies, industries and consumption and will depend on, in part, the roll-out of new technologies and a high degree of coordination amongst and between the industry, civil society and government [1]. The Paris Agreement stipulates that global carbon emissions need to be reduced to near zero by 2050 to avoid catastrophic effects of climate change, meaning that the entire energy system needs to be transformed in just 30 years [2]. For example, the Netherlands has committed to reducing carbon emissions by 49% by 2030 and 95% by 2050 through the replacement of fossil fuel power plants with renewable energy sources, electrification of the transport sector, decarbonization of industries and reduction in agricultural emissions [3–5]. This new sense of urgency is leading to a rethinking of innovation and industrial policy, in which mission orientation and transformative change play a strong role [6,7].

These new forms of innovation policy may seriously alter the type of innovation dynamics that we are used to seeing. Typically, promising technologies undergo an extensive formative phase – often more than 25 years – while fighting existing regimes, such as the fossil fuel industry, before diffusion takes off [8–10]. After a period of experimenting and increasing variety in new designs, a dominant design is selected and clear set of industrial actors form around the dominant design; subsequently, incremental and process innovation occur [11–15].

For societies in need of rapid diffusion of new technologies to help mitigate climate change – this lengthy process may prove too long. Hence, instead of allowing classic innovation dynamics to take their course while fighting a resistant carbon locked-in fossil fuel regime [9,16], a dominant design may be forced quickly as policy attention shifts to rapid diffusion.

Therefore, a different approach may be required in order to foster rapid technological diffusion [7,17,18]. Current mission-oriented innovation policy literature and new notions of transformative innovation policy suggest a need for a higher degree of coordination amongst and

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within industrial sectors, political actors and knowledge institutes than conventional, science-oriented agendas [6,19]. Mission-oriented innovation policies "are by definition about direction – about concrete problems to be solved. In brief, MOIP relies on two pillars: First, setting a purpose for public investments: "big science" meets "big problems". Second, creating conditions for new markets: enabling spillovers from "big science" in form of new demand and supply" (pg. 789) [20].

It is therefore logical to expect government actors to engage with existing industrial actors and work within existing competencies to achieve certain targets linked to grand societal challenges in a shorter timeframe; utilizing and capitalizing on the expertise of incumbents to foster transitions questions typical notions that incumbents are not able to, and actively resist, transitions [6,18,21–24].

Indeed, this is the phenomenon that we observe in the case of offshore wind, in which this promising technology has undergone a different innovation dynamic and pathway than technologies typically experience. It largely bypassed the high-variation, disruptive product testing and technological experimentation phase at the beginning of its development and instead rapidly entered the process and incremental innovation phase, leading to a reversal of a typical technological development pathway. This allowed for over 20 GW (GW) of installed capacity in fewer than 30 years [25–27].

The current success of offshore wind essentially piggybacks on onshore wind and offshore oil and gas installation industries instead of undergoing its own radical experimentation phase [18]. Therefore, the design we see on today's offshore wind farms is remarkably similar to those that were initially tested, namely a three-bladed, upwind turbine placed on a monopile foundation, none of which was originally designed for offshore wind [28,29]. While experimentation has occurred, most initial innovations in offshore wind have gone into process and incremental innovation and were led by large, established companies originating from existing industries rather than startups [28,30] (see Section 2.3 for a detailed explanation).

A focus on radical, high-variation product innovation – such as floating designs or hydraulic pump-based turbines – dedicated to and tailored specifically for offshore wind largely only began after 15–20 years of diffusion and market formation [31–33]. These are the types of innovations that one would expect during the initial period of technological ferment and experimentation.

In response to the need to address the urgency of grand societal challenges on a relatively short timeline, a rapidly formed dominant design, quick focus on process and incremental innovation and rapid technological roll-out has altered classic innovation pathway notions. Many questions, therefore, arise: how did a dominant design arise so rapidly; who is responsible for its creation; what mechanisms fostered it; what are the implications for the rapid diffusion of a technology and its optimal design; what effects does this have on startups and radical innovators? As societies focus evermore on societal goals and grand challenges, we are likely to see this phenomenon more often. This leads us to the following two guiding research questions: *How does a specific socio-institutional architecture inspired by grand societal challenges lead to a rapidly formed offshore wind dominant design and thus largely bypass technological experimentation in the initial stages of diffusion? What mechanisms explain the reversed offshore wind innovation cycle and what conditions are necessary for these mechanisms to unfold?*

This research is divided into two sections. First, we explain the technological trajectory of offshore wind, thus demonstrating our notion that a reversed innovation pathway is indeed observed. We therefore propose a novel innovation pathway based on a new paradigm designed to address grand societal challenges, in contrast to classic notions of innovation trajectories.

Second, we investigate the role that the Netherlands – a formative country in the development of offshore wind in Europe – played in allowing for and encouraging the blistering rate of diffusion while rapidly embedding a dominant design. We propose that a unique institutional construct can lead to a swiftly formed dominant design and quick diffusion of a new technology. To operationalize this notion, we break down offshore wind into its technological innovation system (TIS) as a means to analyze the socio-technical system and to shed light on the conditions that produce a reversed innovation pathway. The TIS framework allows us to deconstruct how and why this innovation cycle has occurred.

2. Theory: Reversing the experimental versus sustaining innovation pathway

2.1. Classic innovation theory

Traditional innovation dynamics literature assumes that technological disruptions – new technological promises that break from an existing product to provide a similar service – first undergo a lengthy period of technological experimentation in which various new and radical ideas are tabled, tried and tested by numerous actors [11–13,15]. When nothing has been done before and there is no roadmap to follow, everyone is free to imagine myriad outcomes. Notions of "technical variation, selection of an industry standard, and retention via incremental technical change that elaborates and extends the standard" follow an evolutionary logic, which professes that new opportunities for technological discontinuities arise and begin to challenge existing paradigms upon which a new winner will ultimately emerge [15] (pg. 605) [34]. Product variation is critical to test both technological suitability as well as consumer and market preference [15]. As technologies mature and consumers pick their preferences, the number of different designs reduces and a dominant design emerges [9,15]. Dominant design is therefore established when the core components of a technology are present in the majority of the available and diffused technological designs, such as the 4-wheeled, combustion engine car, the bicycle with two same-sized wheels, rotating pedals and rear chain or the three-bladed, upwind, horizontal axis turbine [15,35,36]. Subsequently, technological changes come in the form of *process innovation* – automation, scale-up and more efficient production practices – and *incremental innovation* – improving the dominant design by making it stronger, faster, more efficient, more comfortable, safer, etc. [11,13,14,37]. These sustaining innovations are occasionally punctuated by disruptive innovations that threaten the existence of the dominant design and the incumbents that control it, such as the digital camera for Kodak or refrigeration for the ice industry [12,14,15,37,38]. Indeed, product and process innovation can have a high degree of complementarity, thus further embedding and improving the technology [39]. Once established, challenging the dominant design becomes very difficult because the technology has worked its way through the product innovation and technological experimentation phase and a clear winner has emerged [13,35]. Fig. 1 shows the classic technology

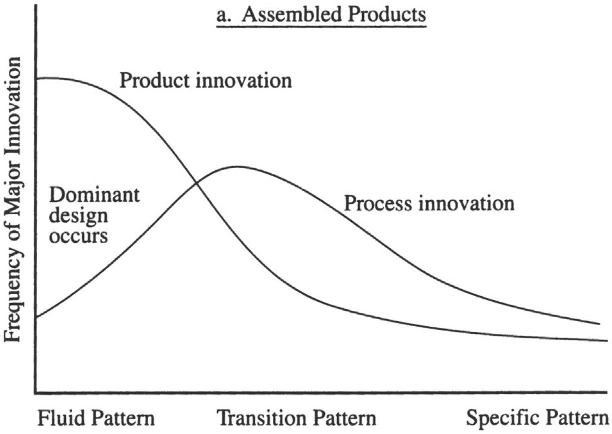

Fig. 1. Classic technological development and diffusion process [11].

product-process innovation curves [11,12]. The *x-axis* represents the chronological development of a technology, in which ‘fluid pattern’ is characterized by ill-defined and uncertain performance criteria and crude production practices, evolving to a ‘specific pattern’ of well-articulated performance expectations and streamlined production practices [12].

2.2. Reversing the pathway

Interestingly, we witness that the development and roll-out of offshore wind has reversed this pathway, in which process and incremental innovation took hold before radical technological experimentation largely occurred. We consider offshore wind to be a disruptive innovation that breaks from existing technologies (onshore wind in this case) designed to provide a similar service (renewable energy) while trying to break from the techno-institutional complex of carbon lock-in [9,16]. Its application, and subsequently technological requirements, in a marine environment, coupled with greater and more consistent wind speeds and few space constraints, indicates that offshore wind represents a fundamental break in technological prospects from onshore wind. Despite serving as a disruption from existing technologies to provide a similar service, offshore wind capitalized on the knowledge previously garnered to quickly roll-out the new technology and rapidly form a dominant design [28]. Offshore wind development occurred through a spatially sticky process of doing, using and interacting by related incumbents rather than experimenting with radical product designs [22,40]. Companies learned from previous projects and improved their processes, leading to a high degree of process and incremental innovation. Further, as explained in Section 2.4, current offshore wind radical experimentation (such as floating offshore wind) clearly demonstrates its novelty as a new technology designed to provide a similar service rather than just continued incremental innovation from onshore wind. Offshore wind is hence part of a new era of technological development that adheres to a new innovation paradigm. Below, we describe the innovation pathway for offshore wind and the rapid convergence on a dominant design, which allows us to propose a new notion of reversed technological development trajectories. Chart 1 shows the growth of European offshore wind from 2002 to 2020.

2.3. Offshore wind dominant design

2.3.1. Turbines

The current offshore wind dominant design is extensively based on the marinization of onshore wind fused with maritime expertise, particularly from offshore oil and gas, dredging and shipping [28,29,41]. Offshore wind is broadly broken down into turbines, foundations, electrical cables and the installation process and strongly resembles the original demonstration farms of the 1990s and early 2000s.

The current offshore wind turbine dominant design is a three-bladed, upwind, horizontal-axis, direct-drive turbine, reaching a power capacity of 8.5–12 MW and projections for even higher capacities [29,42–44], indicating that the unit capacity frontier has not yet been reached [10,42,46–48]. Onshore wind turbines went through a heavy product innovation phase in the 1970s-1980s, allowing for the quick marinization of existing technology [10,29,49–52]. Therefore, demonstration farms in the 1990s simply used onshore turbines. The continually increasing capacity is largely the result of a taller turbine hub-height and blade length, a direct result of *incremental* innovation [44,53].

One major innovation is the shift from traditional gearbox generators to direct-drive systems. Gearbox generators are cheaper, but more prone to failure and less efficient [49,54–56]. The shift was driven by greater reliability, increased turbine size and challenging offshore conditions (accessibility), creating larger benefits for direct-drive systems. However, direct-drive was not a new or novel product, but rather market and technical improvements encouraged its adoption by industry incumbents [49,54] and can therefore be considered as a *discontinuous* innovation designed to *sustain* the current wind turbine industry [47].

In line with process innovation and upscaling of the turbine itself, average offshore wind farm size has steadily increased since the first demonstration farms to 600–700 MW average today [43], which has helped reduce costs through more efficient use of capital-intensive equipment and leveraging economies of scale.

2.3.2. Foundations

Three-quarters of wind turbines are placed on monopile foundations [28,43]. Other foundations, including jacket, gravity-based and suction bucket foundations represent a significantly smaller share of all foundations. Indeed, 6 of the 10 first demonstration farms used monopile foundations. Monopile foundations have increased in height and diameter over the past 30 years, reaching over 120 m in length and 11 m in

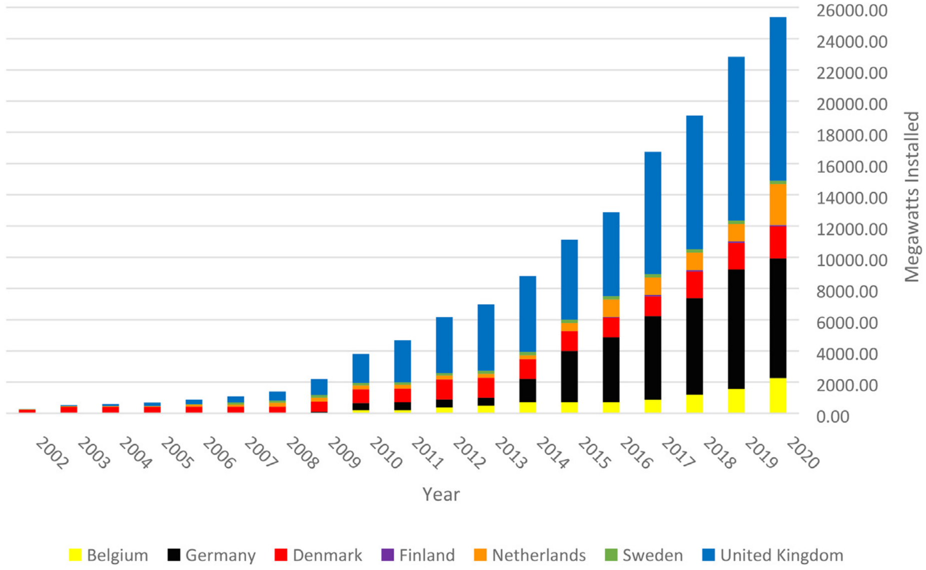

Chart 1. Cumulative installed offshore wind capacity in Europe 2002–2020. N.B. only includes countries with at least one 50 + MW offshore wind farm [31].

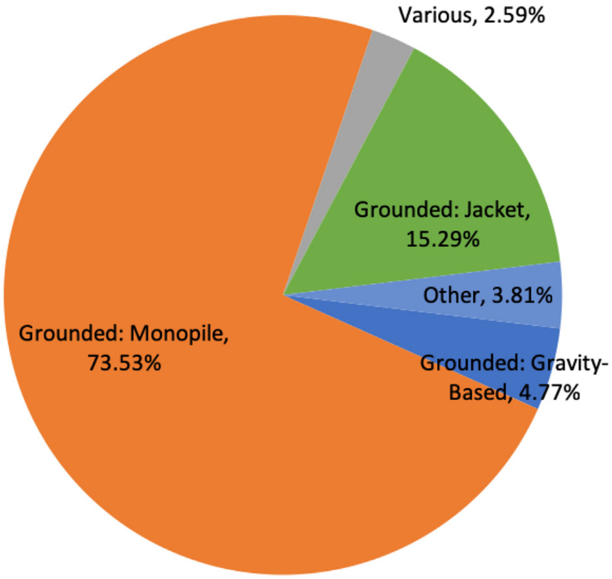

Chart 2. Offshore windfarm foundations by total installed capacity in Europe (until 2022) [43].

width, indicating incremental innovation, while improved production practices indicate strong process innovation [57,58].

Chart 2 illustrates the breakdown of offshore wind turbine foundations by total installed capacity of all European offshore windfarms from 1990 to 2022 [15,59].

2.3.3. Cables

Offshore wind turbines are connected by inter-array cables, which collect the energy and bring it to a substation, which then sends the energy to the onshore grid [47,56]. Innovation mostly comes in the form of higher capacity powerlines and a greater use of more efficient direct current (versus alternating current) systems; this demonstrates incremental product and process innovation driven by incumbents rather than rethinking energy vectors or transmission options (such as energy conversion to hydrogen).

2.3.4. Installation

Finally, the installation process itself has a dominant design. Foundations are hammered into the seabed using loud pile-driving hammers, upon which a transition piece is installed, followed by the turbine itself. The process requires the use of costly jack-up vessels [60,61]. Since the first demonstration farms, there has been a surge in dedicated offshore vessels, particularly jack-ups, heavy lift barges and cable-laying vessels, which are designed and built for the current offshore wind market, indicating process and incremental innovation.

2.4. Current offshore wind disruptive innovation

Therefore, the offshore wind dominant design is remarkably similar to the original designs of the 1990s. This is not to say that innovation has not and does not occur; indeed, quite to the contrary [30,53]. However, this innovation was and is focused mostly on process innovation and incremental improvements rather than radical product innovation [29].

Disruptive product innovation tailored to, and designed from the outset for, offshore wind largely only began around 2008–2009, once more than 1.3 GW had already been installed in Europe; this began with a greater degree of foundation experimentation, including the world's first full-scale floating offshore wind turbine installed in Norway in 2009 by Equinor. The first commercial-scale floating windfarm – the 30 MW Hywind Scotland project – was only erected in 2018 [32]. The first commercial-scale suction-bucket foundations on turbines were installed in 2018 on the 93 MW large-scale Aberdeen demonstration farm in the United Kingdom [33,43]. The world's first full-scale, float-and-sink gravity-based-foundation was commissioned in Spain in 2019 [32,43]. Many other floating and float-and-sink designs are under scale-model and full-scale testing, particularly in Spain, Portugal, France and Japan [62]. Both floating and float-and-sink foundations eliminate the need for loud pile-driving hammers and expensive jack-up vessels.

Numerous wind turbine designs explicitly dedicated to offshore conditions are under development, but none has been installed full-scale and offshore. Examples include a 2-bladed, downwind 6 MW turbine from 2-B Energy (Dutch) under testing onshore and a 500 kW (KW) hydraulic, pumped-based turbine installed in Dutch waters by Delft Offshore Turbine (DOT) (Dutch) [43,63]. SeaTwirl (Swedish) is currently developing a vertical-axis turbine on a floating foundation [43].

These are the types of experimental innovations that one would expect to see at the beginning of the product innovation curve under classic innovation pathway scenarios, not during the take-off or acceleration phases of technological diffusion. While some of these innovations were thought of even in the 1990s, such as floating turbines, no full-scale demonstrations came to fruition until 2009, after the industry was well into the acceleration phase [32,64] The high costs and risks of introducing novel products into the offshore wind industry further exacerbate the challenges of demonstrating new technologies, particularly at a phase when technological lock-in has largely occurred [10,59,65,66]. Some novel products may succeed in modifying or replacing the dominant design, while others will certainly fail, and subsequently rates of both major product and process innovation will reduce as the technology matures either in a new, modified or similar format.

2.5. A new innovation pathway

Based on the innovation pathway we have observed for offshore wind, we propose a reversed innovation curve, in which there is more attention dedicated to rapidly forming a dominant design, and therefore process and incremental innovation in the early stages, rather than radical innovation. In the beginning, there is a rapid ramp-up of process and incremental innovation leading to a better dominant design and more efficient production practices by leaning on the skills and assets of existing industries, which creates technological lock-in [9]; as the dominant design matures, product innovation attempts to step in and challenge this design by proposing solutions that are truly tailored to the unique conditions of the new technology, are less based on existing technologies or industries and are driven by startups rather than incumbents [9]. Fig. 2 plots our proposed product and process innovation curves for a new technology undergoing a reversed innovation dynamic

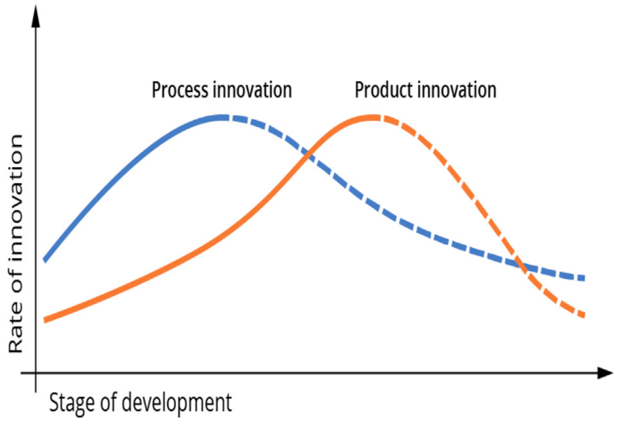

Fig. 2. Reversed process-innovation, product-innovation pathways.

logic. We have represented the downward slope as a dotted line because we have yet to see the effects of the new, innovative technologies that are currently challenging the dominant design. Whether they will supplant the current design or whether the current dominant design will successfully push back and improve its design as a means to resist the challengers remains to be seen.

3. Technological innovation systems: An analytical framework

3.1. Technological innovation systems

To understand the mechanisms of this reversed pathway, we evaluate how a specific socio-technical system has fostered a technological innovation system (TIS) architecture that allows for and facilitates this trend. TISs are composed of actors, networks, institutions and infrastructure oriented around a specific technological artefact and designed to promote its generation and diffusion [67]. It stipulates that a given technological artefact is dependent on a number of system functions, i.e. processes, that feedback on each other in non-linear positive or negative loops [68,69]. Instead of performing a TIS analysis to grasp the processes of the offshore wind innovation system, we use it as a framework to breakdown how and why the design of offshore wind has not followed classic design pathways, as explained below. Table 1 summarizes the seven TIS functions that serve as our analytical building blocks.

3.2. Embedding dominant design

We propose that a certain structural and institutional logic has led to a TIS architecture that embeds and promotes a rapidly formed dominant design leading to a high rate of technological diffusion. This structure encourages sustaining innovation rather than incubating a long period of technological experimentation. We hypothesize that the specific configuration of a TIS – as classified through its functions – can explicitly work to embed a dominant design at a very early stage in a product's development and diffusion. We evaluate the ways in which this specific functional architecture embeds a given dominant design. We do not place a normative dimension on the best TIS configuration, but rather deconstruct how a specific socio-institutional framework develops a unique TIS configuration that embeds dominant design at an early stage and identifies the specific locations within the system where this has occurred. Subsequently, we can highlight potential ways in which system configurers, most often governments, can leave the door open for technological experimentation whilst also reaping the benefits of rapid technological diffusion – a challenging notion as government-driven institutions often become locked-in themselves [9].

4. Operationalization

Based on our understanding of reversed innovation curves, we evaluate how a specific technological innovation system configuration in a given national context was created and subsequently bucked traditional innovation theory pathways. A TIS analysis involves the evaluation of the seven key functions, as explicated above. However, we do not simply evaluate the performance of these functions, but rather focus on their role in creating, supporting and embedding a specific dominant design. Our data is based primarily on interviews with key stakeholders to probe how Dutch offshore wind actors engage with the industry and how these actors interact with the TIS functions.

Specifically, we interviewed 31 key Dutch offshore wind stakeholders between 2018 and 2019; these include established large and small enterprises [ELE] and [ESME] (companies that existed before offshore wind and distinguished at a 250-employee threshold), young SMEs [YSME] and startups as a subset of young enterprises [SUP] [14,71]. We also interviewed networking organizations [N] and government officials [G] [72] (see Appendix 1 for a list of interviews). We used a standardized, semi-structured interview guide, tailored to the interview group (established companies, young companies, networking organizations and government), which allowed for a guided, but open, conversation.

We coded our interviews using NVIVO along a set of criteria, including the seven TIS functions, challenges and approaches to developing products, decisions and difficulties to enter the offshore wind market, perception of Dutch, European and international policies and strategies to allocate resources. For networking organizations, we analyzed their official approaches to facilitating knowledge exchange, collaboration and lobbying for specific policies and perception of existing policies. The interview guide also covered their opinions about the current and past performance of each TIS function. We interviewed government officials regarding policy choices, changes in policy, government allocated resources and support for networking organizations and private businesses, in addition to their opinions about each of the seven TIS functions. Interviewees signed informed consent forms and all relevant quotes were verified with the interviewees and anonymized prior to publication. We complemented our interviews with official policy documents, research program strategies, networking organization mandates, the 4C Offshore Wind Database and news reports from industry journals, such as Offshore WIND, Windpower Monthly and 4C Offshore. Based on our semi-structured interviews and key documents, we evaluate the origin of the offshore wind TIS architecture in the Netherlands and its influence on the innovation pathway.

Table 1
Summary of the TIS functions.

Function	Description
F1 Entrepreneurial activity	Turns knowledge into concrete actions; full-scale/high technology readiness level (TRL) product testing; incumbent diversification; startup activity.
F2 Knowledge generation	Industrial and basic research & development. It encompasses 'learning by searching' and 'learning by doing'. Typically occurs at universities, research institutes and private companies, including R&D departments or on projects.
F3 Knowledge diffusion through networks	Networks, industry associations, business-business and business-academic partnerships that facilitate knowledge exchange through 'learning by interacting' and 'learning by using'.
F4 Guidance of the search	Government discourse in support of (or against) the industry through goal-setting, visions, etc.; also based on industry/client demand, pressure on core industries (for diversifiers) and societal pressures.
F5 Market formation	Formation of protected niche-space, government-backed commercial markets or non-subsidized market demand.
F6 Resource mobilization	Governments and companies mobilize resources to invest in and develop new technologies; this includes the availability of funds to support research, dedicated institutes, in-house R&D departments, mergers & acquisitions, and human resources.
F7 Legitimacy/counteract resistance to change	Promoting the technology as legitimate and counteracting industrial, political and civil-society resistance to change. Includes government, private and civil-society lobbying efforts for and against the technology.

[68–70].

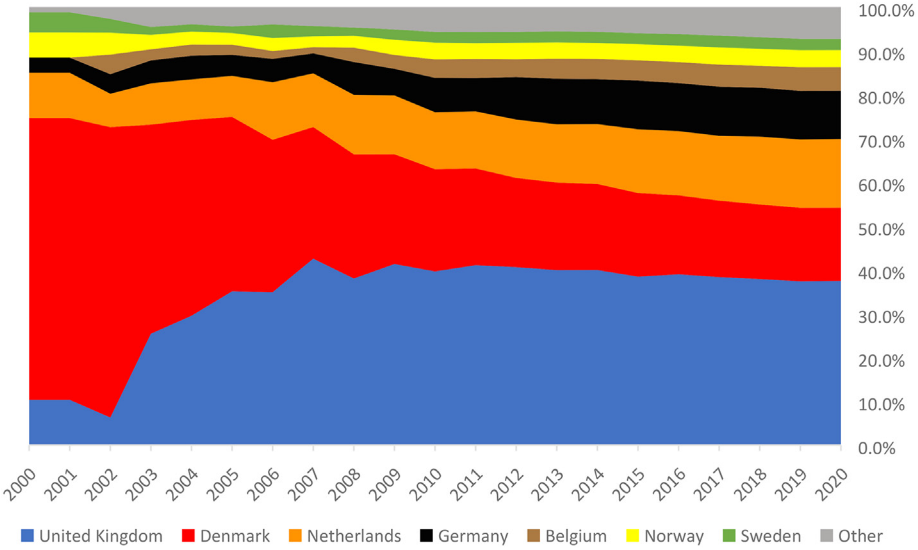

Chart 3. Share of stakeholder activity on European offshore wind farms [31].

5. Results: Creating a dominant design

5.1. F1 Entrepreneurial activity

The Netherlands is extremely active in the offshore wind industry, accounting for more than 15% of all European offshore wind activity in 2020 (up from 7.6% in 2002) despite its market share fluctuating from 6.7 to 10.3% in the same period [43]. Chart 3 shows the share of the leading offshore wind stakeholder countries from 2000 to 2020 on European offshore wind farms, which demonstrates the Netherlands' (orange) consistently strong position. 'Stakeholder activity' is defined as a contract entry in the 4C Offshore Database (2019) with a 'stakeholder' being a company or organization that has received the contract.

Eighty percent of Dutch stakeholders are incumbents or established SMEs, all diversifying from industries such as oil and gas, maritime, shipping, dredging and geological surveying [43]. The new offshore wind industry was immediately populated with existing companies leveraging existing skills and assets. Even at the beginning of offshore wind in the 1990 s, startups were few and far between; for example, a consortium of major Dutch construction and offshore maritime incumbents and established onshore turbine companies developed the 2 MW Lely Dutch demonstration farm in 1994 [43,73]. The same key incumbents, plus a Vestas (Danish) onshore turbine, undertook the second Dutch demonstration farm in 1996. The Dutch incumbents on these initial farms maintained a strong role in the rapidly developing Danish, British and then German markets. For example, the first large-scale offshore wind farm – the 2002 Danish 160 MW Horns Rev 1 – comprised 10 Dutch incumbents [74].

According to interviews with [ELE 1–9] and [ESME 1–4], these companies leveraged their existing resources, skills, assets and experience to rapidly deploy offshore wind farms around Europe and focus on the skills that they already possess, in line with classic innovation theory [9].

Young companies, for their part, have two strategies to enter the offshore wind market: they can either try to introduce a new product that will disrupt the current dominant design [SUP2,4,5] or they can attempt to introduce products or systems that will help improve the current design, hence furthering process and/or incremental innovation [SUP1,3]. Many Dutch startups are focused on improving the current system. For example, (at least) three Dutch startups are working to improve the monopile pile-driving process: Fistuca, SeaState5 and GBM Works. These companies may have an easier time in attracting investments from incumbents because 1) they are not a threat to the current dominant design and 2) they strive to improve the dominant design by making the dominant design more efficient, cheaper, faster and more environmentally friendly, (*incremental* and *process* innovation) [75,76].

However, startups trying to introduce a disruptive innovation that would render certain incumbents obsolete, such as by eliminating the need for jack-up vessels, face not only classic product development hurdles, but also active resistance and less support from well-established and well-connected incumbents. According to one startup that is trying to introduce a radical innovation:

So, in March 2017, the playing field was still open for Borssele V [*publicly sponsored full-scale demonstration site*]. A lot of people were involved in trying to get it. Our enemies basically tried to keep us out of the loop. Who was the enemy? And now we get the concept. The enemy is everybody who owns bespoke or purpose-built work ships. Jack-up rigs. Anybody who has this capital-intensive fleet of boats that was actually built a long time ago for the oil and gas business. They need to keep those boats afloat and working. [SUP2]

The current Dutch on– and offshore full-scale testing sites are not designed to help disruptive technologies prove their merits. Indeed, they continue to promote process and incremental innovation and play strongly into the hands of incumbents. The Borssele V Innovation zone failed to introduce radical new innovations developed by startups, according to every interviewee knowledgeable about the site, including incumbents, SMEs, startups, the government and networking organizations; the tender was won by a consortium of incumbents led by the Dutch multinational van Oord, which chose MHI Vestas' turbines [43,77]. The only major innovation is the introduction of the single slip-joint, which eliminates the need for a transition-piece connector between the foundation and the turbine through two conical-shaped connectors. While an important milestone in the development of offshore wind, the single slip-joint is still a *continuous* innovation designed to *sustain* the current design, industry standard and incumbents.

Onshore test sites, such as the Maasvlakte II, receive little financial support, creating a need for partnerships and external funding to carry out tests [N1] [48]. General Electric Renewable Energy (American-French) is currently testing a 12 MW offshore turbine at the Maasvlakte II, which is the next step in increasing the nameplate capacity of the current dominant design, indicating *incremental* innovation driven by a major industry incumbent.

In another example, the Dutch startup Fistuca tested a quieter pile driving hammer at the Maasvlakte II after a major investment by the Dutch oil and gas incumbent, Huisman [42,48,78] and a second round of investment from IHC IQIP (Dutch), one of the world's largest monopile hammer companies [79]. According to the International Energy Agency, …Conservative design practices – adopted from other offshore industries – are likely to be used for turbine design…Offshore turbines could adopt a design other than the mainstream three-blade concept, e.g. two blades rotating downwind of the tower. Improved alternative-current (AC) power take-off systems or the introduction of direct-current (DC) power systems are also promising technologies for internal wind power plant grid offshore and connection to shore [53].

Disruptive innovators thus face high barriers to entry due to a strongly embedded and supported dominant design populated by incumbents, a problem exacerbated by traditional market entry barriers in a high-CAPEX industry [SUP1-5]. Hence, we see that Dutch entrepreneurial activity performs very well for established companies, while actively embedding dominant design and resisting disruptive innovation.

5.2. F2 knowledge development

According to our interviews, all established companies [ELE1-9 & ESME1-4] have either formed designated offshore wind research departments or, at minimum, dedicated significant resources to offshore wind knowledge development. These private-sector R&D endeavors naturally seek to improve a company's existing services and products and do not engage in developing radical designs because 1) they seek to improve their ability to do what they already know how to do; and 2) fear that radical design will disrupt their current offshore wind business models, a standard perspective from existing actors [23,80]. This concept further applies to research collaborations incumbents engage in (see Section 5.3). According to one incumbent:

Well, we have a philosophy in innovation that is based on the principle: If there is an innovation appearing on the horizon that helps the concept of [*our core product*] to be implemented further in time, bigger or whatever, a benefit to the concept, we would like to support and participate. Not necessarily to build silent hammers or necessarily to build whatever kind of product, but more to help the [*product*] as a concept to live longer. And as a consequence, our company benefits from that. So, our innovation philosophy is supporting all sorts of startups that helps the concept of [our *product*] to survive longer or getting a better applicability. [ELE8]

On the other hand, basic R&D knowledge development – low technology readiness level (TRL) – performs very strongly and is financially and logistically supported by the Dutch government. Initially, there is significant support for radical, incremental and process innovation. There are at least nine different government supported research institutes that focus on offshore wind in the Netherlands, including TNO, Marin, Deltares and DUWIND [81]. A number of incubators are also present, such as YES!Delft and Buccaneer, which provide low-cost lab space and support for startups and university spin-offs. Government support for radical product innovation at low TRLs is strong. For example, Monobase Wind is leveraging low-TRL funding it received from the government to develop a gravity-based float-and-sink foundation concept [82].

However, bringing these designs from small-scale to full-scale is often a breaking point for young innovators, known as the *valley-of-death* [83]. In addition to the high capital costs of innovation, the institutional structure of knowledge development is a barrier for startups. Two mechanisms are at play: first, the Top Consortium for Knowledge and Innovation – Offshore Wind (*TKI Offshore Wind*) explicitly promotes "*Cost Reduction and Optimisation*" as its first core program line, with the other two being "*Integration into the Energy System*" and "*Offshore Wind and the Environment*" [84]. Indeed, the concluding remarks of the official 2019–2020 TKI Offshore Wind Program are,

The TKI Wind op Zee [*offshore wind*] facilitates research, development, demonstration, valorization, knowledge transferal, innovation dissemination, (international) cooperation, education, and market development – all activities aiming to stimulate cost reduction and create economic benefits. These activities contribute to the development of generating offshore wind energy at a large-scale and at the lowest possible societal cost [84].

Second, Dutch funding mechanisms mandate an increasing percentage of external investment as the innovation climbs the TRLs, a concern raised by every high CAPEX startup we spoke with [SUP1-5] (see *resource mobilization*, below) [85]. This is also the moment when testing becomes more expensive and occurs offshore. Hence potential investors, who are often incumbents, are more likely to invest in knowledge development that helps them improve their current processes and products and not in disruptive innovations.

Interestingly, some signs point to potential investment pathways from incumbents that are engaged in a different part of the offshore wind value chain. For example, the Delft Offshore Turbine was installed on a 1:5-scale offshore in partnership with the monopile incumbent Sif and the oil and gas incumbents Heerema and van Oord (incumbents from non-turbine segments of the offshore wind industry), along with funding from TKI Offshore Wind [63]. Since this project does not pose a fundamental threat to their business models, they may show some willingness to invest. However, incumbents that are not experts in specific sectors may also be reticent to invest in unknown business endeavors.

As such, we can conclude that knowledge development in the Netherlands allows for technological experimentation at low TRLs, whilst in-house R&D and high-TRL product development emphasize process and sustaining innovation.

5.3. F3 knowledge diffusion

There are numerous formalized networking organizations dedicated to offshore wind, including the Offshore Wind Innovators, the Port of Rotterdam Offshore Wind Coalition, the Netherlands Wind Energy Association (NWEA) and the TKI Offshore Wind/GROW R&D funding and networking organization [86–88]. These organizations strongly promote active collaboration and knowledge sharing between startups, incumbents and knowledge institutes and provide research funding, onshore testing space, laboratory facilities and visibility programs. This indicates that there is a strong concentration of knowledge development and diffusion in the Netherlands; however, the high degree of collaboration with incumbents and established companies further fosters incumbent-driven innovation initiatives [N2, ELE7]. For example, the Offshore Wind Innovators initiated an award program in which incumbents put forward a series of challenges they face in the offshore wind industry; these challenges are then addressed by participating startups, with the winning companies given preferential access to meetings and greater visibility [88,89]. Van Oord's recent challenge to improve monopile hammering noise mitigation presents an opportunity for a startup or young company to assist van Oord in improving its existing monopiling methods [89]. For disruptive innovators seeking to eliminate the need for noise mitigation measures in the first place – for example, by removing the need for monopile hammers – this type of award system puts them at a disadvantage. Further, the TKI Offshore Wind grants explicitly seek to foster incumbent-startup collaborations [90]. There are over 40 participating incumbents and established SMEs in the TKI Offshore Wind program [91]. This can be a powerful mechanism to help companies access influential industry partners and potential investors, but also ensures that incumbents have a say in the research agenda. One incumbent stated.

We've had an innovation challenge where we invited companies from the whole of Europe…We're a European company and don't see the Netherlands as an isolated part of the offshore wind market…We have a company program there. And I think it was awarded last week. I think it was a [*country deleted*] company who won that. That's all startups. We invite them to be part of it [I7].

If incumbents continue to play a strong role in knowledge development through formalized knowledge diffusion mechanisms, strategies will focus on helping incumbents improve their existing products and services and hence further process and incremental innovation over disruptive product innovation.

5.4. F4 guidance of the search

According to policy documents and interviews, the vision for offshore wind in the Netherlands was sporadic, tumultuous and inconsistent since the early 2000s until 2013–2014, despite an initial commitment in 2002 for six gigawatts by 2020 [G1-3, ELE7-9, N3-4] [92–95]. Subsequently, the Dutch Roadmaps to 2023 and 2030 implemented a strong institutional focus on cost reduction and market uptake, as well as the Energy Agenda to 2050, which all highlight the success of current cost reductions, need for further reductions and massive offshore wind deployment [3,96,97]. While these reports do highlight innovation, emphasis is placed squarely on the ability to reduce costs and increase efficiency of the current model. The roadmaps lay out visions for 4.5 GW by 2023 and 11.5 GW by 2030 [96]. Indeed, even the Dutch Energy Agenda until 2050 targets cost reductions, subsidy free offshore wind farms and massive offshore wind roll-out as key components of the energy transition: [It will] “Continue with cost price reduction and promoting innovation and competition. The aim is that offshore wind farms for which a tender is issued from 2026 will no longer need to be subsidized” [3]. In fact, the Dutch will have the world’s first subsidy free offshore wind farm commissioned in 2023 – the 700 MW Hollandse Kust I/II – tendered only one year after publication of the Energy Agenda. The roadmaps lay out strong and consistent policy visions, providing much needed confidence in the market, and hence are directly tailored towards increasing the diffusion of offshore wind while driving costs down through incremental and process innovation.

You know, one thing to say is that all countries except for Holland do have some sort of local content built in their system. Especially the UK. The Dutch just wants to have the cheapest way to get offshore wind going. But we do see the logic of the policy. So, as a tax payer, privately I fully see the logic of the Dutch system, which is towards the tax payer the most economical way of going forward [ELE8].

They are subsequently less directed towards introducing disruptive product innovation [96,97].

Due to strong visions by governments around Europe, incumbents were not only well poised to enter the market and learn by doing, using and interacting, but also pushed private sector guidance towards process and incremental innovation [ELE1-9]. Many Dutch incumbents were approached by international stakeholders to help them build offshore wind projects [ELE7-9]. These projects were mainly pushed by the Danish, British and German governments – which established mandates to roll out offshore wind farms [24,41]. Companies then sought out existing expertise to which Dutch companies were well-poised to respond. According to one Dutch incumbent.

The Danes wanted to get rid of their dependency on fossil fuels in those days. And that sparked the offshore wind industry…And at that time when people were asking for a [*company product*], there was actually only one company who had the ability to make [*product*] of the size that they needed. So, logically, from a let’s say technological search they landed with [*company name*] as being most probably the only company able to come close to what they needed in size and weight [ELE8].

Emphasis was placed on finding the cheapest options available, regardless of the companies’ origins. This successfully pressured the industry to drive costs down; however, it also meant that the government was less willing to support potentially breakthrough innovations at higher TRLs. As is clear, public and private guidance has focused and targeted rapid cost reduction and technological diffusion at the expense of potentially breakthrough technologies.

5.5. F5 market formation

Market formation in the Netherlands did not solidify until legally binding EU targets were enacted as part of the National Energy Agreement to reach 16% renewable energy by 2023 [97]. The Netherlands constructed two one-off offshore wind farms in 2006 and 2008 (108 MW and 120 MW, respectively) after two small demonstration farms in the 1990s; this was followed by a long lull in construction activity, which peaked again in 2015 and 2016 with two small and one large offshore windfarms of 129 MW, 144 MW and 600 MW [74]. Due to the long lead time and previous inconsistent policy, regular, annual offshore windfarm commissioning will not be achieved until 2020. The Dutch government now undertakes the responsibility for the grid connection, geological surveying and permitting process, thus further reducing risks and uncertainty associated with such large-scale projects [97]. While both are important milestones, they also place an emphasis on cost-cutting measures and less on investing in (currently) expensive, potentially breakthrough technologies for the future.

Due to the strong vision and government-backed market formation, incumbents are willing to invest more resources into furthering their current technologies. For example, Sif (which produces one-third of all European monopiles) recently opened a new production facility at the Maasvlakte II, increasing production capacity and ease of access to the North Sea, a direct example of process innovation [47,57,98]. These companies further embed dominant design by improving production and installation processes.

Established companies played and continue to play a strong role in the formation of market policies. Indeed, six of the nine incumbents we spoke with explicitly mentioned that they work with and advise the government on policy. According to one: “[Interviewer]: Do you actively work with them [*the government*] in terms of promoting offshore wind? [Interviewee]: Yeah, and they’re also approaching us, so it’s both ways” [ELE4]. According to another incumbent:

We started interacting with the Dutch government, trying to help them to shape the policy in the best way possible…So when the Energy Agreement came about, our company became more interested, spent some resources on it and our main sort of goal during that period was to create an offshore wind policy that would fit [our] approach and the good thing was that within [our company] there was only one thing on the agenda and that was: cost reduction. In the Netherlands, the main thing on the agenda was: offshore wind is too expensive, it costs too much… So, from a policy perspective, the thing you needed was to bring down the costs. That was what [we were] working on…and that was what the government was looking for. In our interaction with the Ministry, the central point of every conversation was driving down the costs. We could explain which approach in our view would help to bring down the costs [ELE9].

5.6. F6 resource mobilization

In close synchronicity with the other TIS functions in the Netherlands, government allocated resource mobilization strongly supports R&D at the basic research level, which, according to one interview [N3], provides more than 100 million Euros in annual funding. At the low end of the TRL-scale, funds are widely available and with minimal conditions, thus supporting product innovation [SUP1,5]. However, as the technology advances, the rules stipulate a greater share of in-kind funding, up to 50%, to access public money; this is also the moment when more funding is needed due to the capital intensive nature of large and full-scale testing [SUP2-5] [85]. For a startup, this is often a breaking point. According to one networking organization, the TKI Offshore Wind program offers significant funds that are not even entirely spent due to elusive and challenging conditions for receiving the grants [N3]. One startup mentioned.

Once we started it was part private and part government. Which you also need for government support…Yes, you get 80%, which sounds

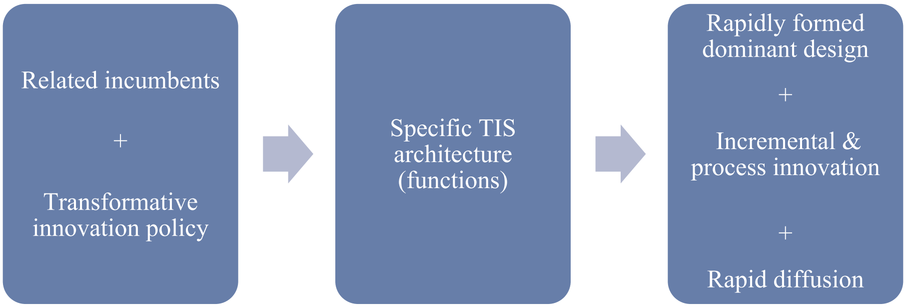

Fig. 3. Conditions for a reversed innovation development cycle.

like a lot, but they do need to be convinced that you somehow can get the twenty percent yourself…That's a challenge: Getting this funding in. I know that I'm of course biased in this, but this is really not helping innovation. It's just taking us too much time to get funding [SUP5].

One high CAPEX startup developing a radical product intentionally steered clear of government funding, citing bureaucratic complexity and strict in-kind funding requirements: "We don't want to spend too much time on getting subsidies because it's quite an effort to get one. And if you have one you need money from other sources anyway. So… We're not too fond of subsidies" [SUP4].

Even government funding for the Borssele V offshore demonstration zone was insufficient to attract radical product innovation, as discussed in *Entrepreneurial activity*. To the contrary, only a consortium of incumbents that had already won the tender for the next-door 700 MW commercial-scale Borssele III/IV were able to bid on the demonstration farm. Every interviewee familiar with the Borssele V project explicated that this severely hindered potentially breakthrough innovation. One established SME stated.

[…The principle of having a demonstration site is brilliant. We need more of those because it's really difficult to bring something new to the market. And an innovation site is then a perfect location for that. But your project conditions need to be right. And I think what the Dutch government did was to combine the great idea of having a demonstration site with 'Hey, everything in offshore wind is going down, so let's put the subsidies…at the same level as [*the commercial-scale*] Borssele III/IV. Borssele III/IV is a windfarm with I think forty plus foundations, with forty plus turbines, with large operations and maintenance costs where you can actually divide all the cost of the operations and maintenance over forty foundations, forty turbines. In Borssele V, you had two [*turbines*] [ESME2].

Both incumbents and established SMEs invest financial and human resources into offshore wind activities. Indeed, four of the seven incumbents and two of the four ESMEs we spoke with were engaged in mergers and acquisitions as an explicit strategy to bolster their offshore wind portfolios. While mergers and acquisitions are certainly not an unusual phenomenon, it demonstrates the increasing power and consolidation amongst incumbents and established SMEs to further the dominant design in which they are heavily vested.

5.7. F7 Legitimacy/counteract resistance to change

According to every networking organization and most established actors, resistance from the oil and gas lobby has largely faded and even turned its support towards offshore wind, achieving widespread legitimacy; this comes from both the business community as well as the government and civil society. Due to the greater acceptance of offshore wind by incumbents, they show willingness to enter, participate and invest. According to one networking organization.

We know that oil and gas will become less important due to the energy transition, and I think that raises the attention for the development of offshore wind…I think these companies, for instance [*established O&G incumbent*], is very oil and gas minded, but you also see an increase in focus on the offshore wind industry. So, I think all these companies have to change in order to keep up with the world to be honest [N1].

Hence, they focus their activities on doing what they already know how to do and on leveraging their existing skills and assets. Not only are incumbents able to leverage their resources, but they also actively engage in setting the policy agenda. While many studies have shown that incumbents are ill-prepared to engage in new markets and often actively resist transitions, in some instances, such as offshore wind, we see that they can help foster diffusion [99,100]. Legitimacy from incumbent industries can therefore act as a catalyst for change under the right institutional conditions.

6. Discussion

6.1. Two key conditions for reversed product-process innovation

Our results show how a specific innovation system configuration fosters and promotes dominant designs from a very early stage, which has the benefit of rapid technological diffusion and strong employment prospects. Two key themes are visible across the seven TIS functions: 1) a large presence of domestic incumbents in related industries; 2) a specific and strong government-backed vision and market formation. We visualize this in Fig. 3, below. First, incumbents have the skills, competencies, resources and assets to readily diversify into the new industry [22,101,102]. The Dutch offshore wind industry is extensively populated by incumbents and established SMEs. Further, existing competencies in related industries positively positions incumbents to enter the offshore wind market on a large-scale [22,103]. The fusion of onshore wind and offshore oil and gas made this possible for the current offshore wind design. Highly related technologies are able to capitalize on the product design experimentation phase that these industries previously went through. This means that entire industries can be supported through learning-by-doing and applying existing skill-sets and knowledge [22,40].

Second, there must be a strong government driven market pull and transformative innovation policy upon which these diversifying incumbents can capitalize. Dutch companies were able to leverage new markets created in Denmark, the United Kingdom and Germany before reshoring their expertise to the Netherlands [24,41,80,103,104]. In addition to the demand-pull from other European countries and stated ambitions within the Netherlands, Dutch strategies explicitly guide a transformative innovation pathway to rapidly form a dominant design. R&D funding mandates a high-degree of co-financing from the private sector, business-to-business networking organizations are extensively populated by incumbents, weak high technology-readiness-level demonstration programs limit radical experimentation and strong stated ambitions for an offshore wind market all work towards locking in a dominant design. These lock-in mechanisms within a technology are very similar to approaches towards locking in entire industries.

According to Unruh (2000), “It should be emphasized that carbon lock-in is not conceptualized as a permanent condition, but instead a persistent state that creates systemic market and policy barriers to alternatives” (pg. 818) [9].

These conditions led to the formation of a specific innovation system configuration that actively embedded a dominant design at a very early stage, hence leading to rapid technological diffusion.

6.2. Pros and cons of rapid dominant design formation

One of the major benefits of such a system configuration is rapid technological diffusion. For renewable energy and the energy transition, rapid diffusion through a demand-pull approach is essential to achieving carbon reduction as there is insufficient time for potentially breakthrough technologies to undergo an extensive R&D-to-market cycle [8,10,45]. Additionally, significant employment opportunities exist, which is of particular importance as many workers may need retraining as current industries decline.

On the downside, our research demonstrates that a rapidly formed dominant design impedes breakthrough innovations and high-TRL experimentation as it emphasizes incremental and process innovation, potentially leading to a suboptimal design. Essentially, designs that could have arisen based on unique offshore wind conditions were not prioritized. This is visible as many new product designs are only now arising. Under a classic innovation scenario, this would have happened at the beginning of the technological innovation curve, not after significant diffusion. Whether disruptive designs ultimately break the current mold remains to be seen.

6.3. Getting the best of both worlds?

The benefits of rapid diffusion of renewable energy technologies cannot be understated; if countries are to meet their respective climate targets, an unprecedented level of technological roll-out is necessary. Hence, leveraging existing industries and creating specific innovation system configurations can help facilitate this trend, as can be seen in our case study of offshore wind [22]. However, overreliance on industries that were not designed for the new technology from the outset may also lead to a less-than-perfect product, cognitive lock-in, vulnerability and risk of the ‘incumbent’s curse’ [105–107]. Therefore, it becomes key to leave room for high and low TRL experimentation whilst also emphasizing strong visions, rapid diffusion and cost reductions. In the case of the Netherlands, low TRL disruptive innovation is well-supported, whereas financial, political, networking and institutional support at higher TRLs is constraining. There is hence a risk that singularly focused Dutch companies, such as jack-up vessel providers or monopile producers, will become obsolete in the event that fundamentally different dominant design patterns emerge, such as floating offshore wind or turbine designs no longer requiring monopiles [9]. Reducing in-kind R&D funding requirements and facilitating more full-scale offshore demonstration sites may help allay these issues and potential risks without hindering the rapid diffusion of offshore wind [108].

6.4. Are we likely to see this more often?

As societies shift from technology specific endeavors towards addressing complex grand societal challenges necessitating a higher degree of coordination on an increasingly reduced timeline, it is likely that system architects – usually governments – will seek to leverage existing industries and related technologies to enact change. Hence, it is probable that there will be less of an emphasis on promoting many years of technological ferment and experimentation and rather a greater focus on rapid deployment and learning by doing, using and interacting. This may help promote a quicker diffusion of critical technologies, but at the expense of experimentation. It is likely that the key players in new endeavors will be incumbents from other industries rather than startups. Hence, finding a delicate balance between ensuring rapid technological diffusion and insuring against design lock-in and overly homogenized industries remains a challenge.

This research has focused on the rapidly formed offshore wind dominant design in Europe, which was a direct result of a strong market-pull from a core set of countries and an explicit and targeted transformative innovation policy approach that capitalized on the assets, skills, knowledge and resources of incumbent industries and actors. The specific dominant design that was formed was further based on certain physical conditions, such as a shallow and sandy sea bottom in the North Sea.

We suggest that the mechanisms for the rapid formation of a dominant design through transformative innovation policies will be similar across the globe; however, the actual resulting dominant design may be different. For example, the deeper and rockier Japanese seabed or institutional constraints in the United States – particularly the vessel-restrictive Jones’ Act – may force a different dominant design [109,110]. Nonetheless, we expect that transformative innovation policies will display the same characteristics in the formation of dominant designs regardless of the geographic location. That is to say that regardless of the resulting dominant design, transformative innovation policies will create strong conditions to rapidly form a dominant design while heavily engaging with relevant industries.

However, there are limitations in certainty since there are no established markets outside of Europe and China. Further studies on the offshore wind development pathway in China or follow-up studies in the United States and the rest of Asia, once these markets emerge, could shed further light on these notions. Studies on other technologies, such as electric vehicles, could provide fertile ground for comparison.

7. Conclusion

Offshore wind is a unique, new and thriving industry that bucks traditional innovation patterns whilst offering extraordinary potential for coastal countries to increase their share of renewable energy in the energy mix. This research has elucidated the innovation system framework for which a new technology can first undergo a period of rapid process and incremental innovation and technological diffusion and only subsequently enter a technological experimentation phase. Through an operationalization of the Dutch offshore wind technological innovation system, we evaluate the strategies, tactics, mechanisms and conditions that allow for and embed a dominant design, which occurs by engaging in a highly coordinated political strategy while actuating the skills and competencies of related incumbent industries. Transformative innovation policies and mission-oriented innovation systems are likely to play a stronger role in decision making, and therefore will encourage innovation pathways that are divergent from traditional models [111]. This is a phenomenon that we can expect to see across different regions and for different technologies so long as the government chooses to engage in transformative innovation policies coupled with access to highly-related incumbent industries. The dominant designs themselves may turn out to be different in different regions, even within one technology, such as offshore wind; however, the process to achieve the dominant design may be remarkably similar. Policy makers hence may need to not only ‘unlock’ locked-in regimes, but also capitalize on existing regimes as part of a rapid transition.

Declaration of Competing Interest

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

Appendix 1. List of interviews

Code	Actor type	Date of interview	Interviewee's role
ELE1	Established large enterprise	30.5.18	Head sale's manager
ELE2	Established large enterprise	5.6.18	R&D manager
ELE3	Established large enterprise	19.6.18	Commercial manager
ELE4	Established large enterprise	9.7.18	Business development and acquisition manager for offshore
ELE5	Established large enterprise	12.7.18	Head of business development
ELE6	Established large enterprise	5.12.18	Head of offshore wind business unit
ELE7	Established large enterprise	11.12.18	Business developer
ELE8	Established large enterprise	27.3.19	Chief commercial officer
ELE9	Established large enterprise	27.5.19	Former CEO
ESME1	Established SME	29.6.18	Business manager
ESME2	Established SME	18.7.18	Manager of renewables
ESME3	Established SME	25.7.18	Commercial general manager of wind
ESME4	Established SME	15.11.18	Managing director
YSME1	Young SME	16.7.18	CEO & founder
YSME2	Young SME	19.7.18	CEO & founder
YSME3	Young SME	24.7.18	Project leader
YSME4	Young SME	23.11.18	Head of offshore wind business unit
YSME5	Young SME	30.11.18	CEO
YSME6	Young SME	27.3.19	Co-founder
SUP1	Startup	16.7.18	General director
SUP2	Startup	17.7.18	CEO & founder
SUP3	Startup	26.7.18	CEO & founder
SUP4	Startup	29.11.18	Head of technical development
SUP5	Startup	6.12.18	Project developer
N1	Networking organization	7.6.18	Coordinator
N2	Networking organization	25.6.18	Manager/coordinator
N3	Networking organization	20.12.18	Director
N4	Networking organization	20.12.18	Former director
G1	Government agency	24.6.19	Senior advisor
G2	Government agency	4.9.19	Offshore wind project leader
G3	Government agency	11.9.19	Senior advisor for offshore wind

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