Offshore renewable energy: threats and opportunities in the post-2030 Netherlands

A report commissioned by the Netherlands Enterprise Agency (RVO) &
TKI Wind op Zee (Top consortium for Knowledge and Innovation Offshore Wind)

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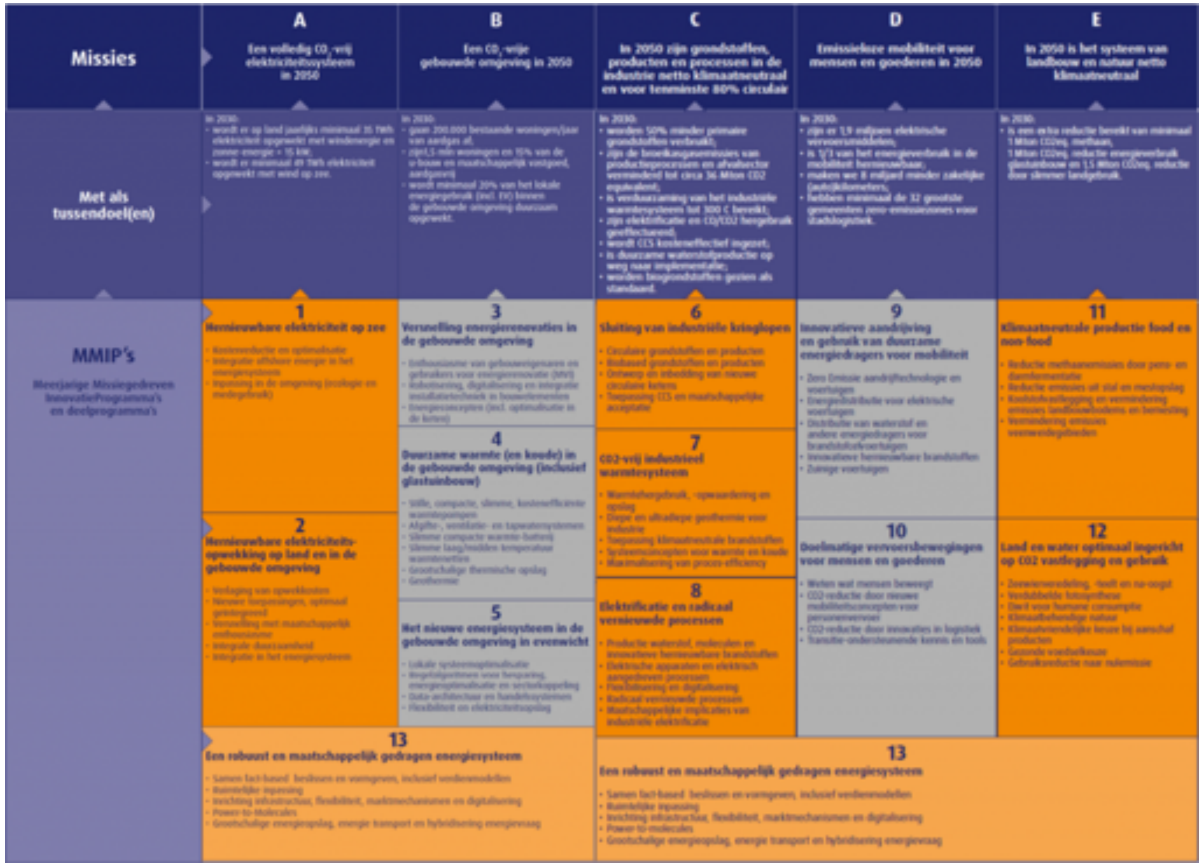
Introduction

5 missions for a carbon-neutral 2050

- The Netherlands has elaborated 5 central missions to achieving a carbon-neutral society by 2050
- Mission A is a fully decarbonized electricity sector
- Mission A1 is the cornerstone of this program and requires a massive 38-72 GW diffusion of offshore renewable energy by 2050 (Northsea Energy Outlook)
- The mission is about rapid diffusion, cost reduction, system integration and upscaling, leading to certain technology choices
- It does not focus on industrial development and growth
- Survival of the Dutch industry is not automatic because disruption can occur outside of the Netherlands that affects the industry
- For ex., what would happen if a different offshore wind foundation – such as gravity-based float-and-sink – or offshore renewable energy technology, like tidal energy, became the global standard? What would the effect be on the industry? Is the industry prepared?



Ministry of Economic Affairs and Climate (2019)

Research goal

An overemphasis on carbon mitigation may present a danger to the offshore renewable energy sector's long-term survival. If disruptions to technologies or markets occur, what would the impact be on the Dutch industry? Therefore, it is unclear whether the Netherlands has a resilient offshore renewable energy sector or is locked into specific technological choices.

Ideally, it is possible to capture the **double-dividend** by combining a successful carbon mitigation strategy with economic and industrial development, leading to **green growth.**

We therefore propose that a well-performing industry needs to be **balanced** between both the successful diffusion of a specific technology – such as offshore wind – and the ability to create, innovate, improve and adapt to disruption. If not, there may be a **threat of collapse**, loss of market share and a failure to achieve goals, such as a carbon-neutral society.

In this report, we investigate how locked in the Dutch industry is to diffusing specific offshore renewable energy technologies in specific markets or whether it is also able to adapt to potential disruptions in the future.

General research question

To evaluate whether the Netherlands can address potential threats and disruptions, we ask the following question

How vulnerable or resilient is the Dutch offshore renewable energy sector to disruption?

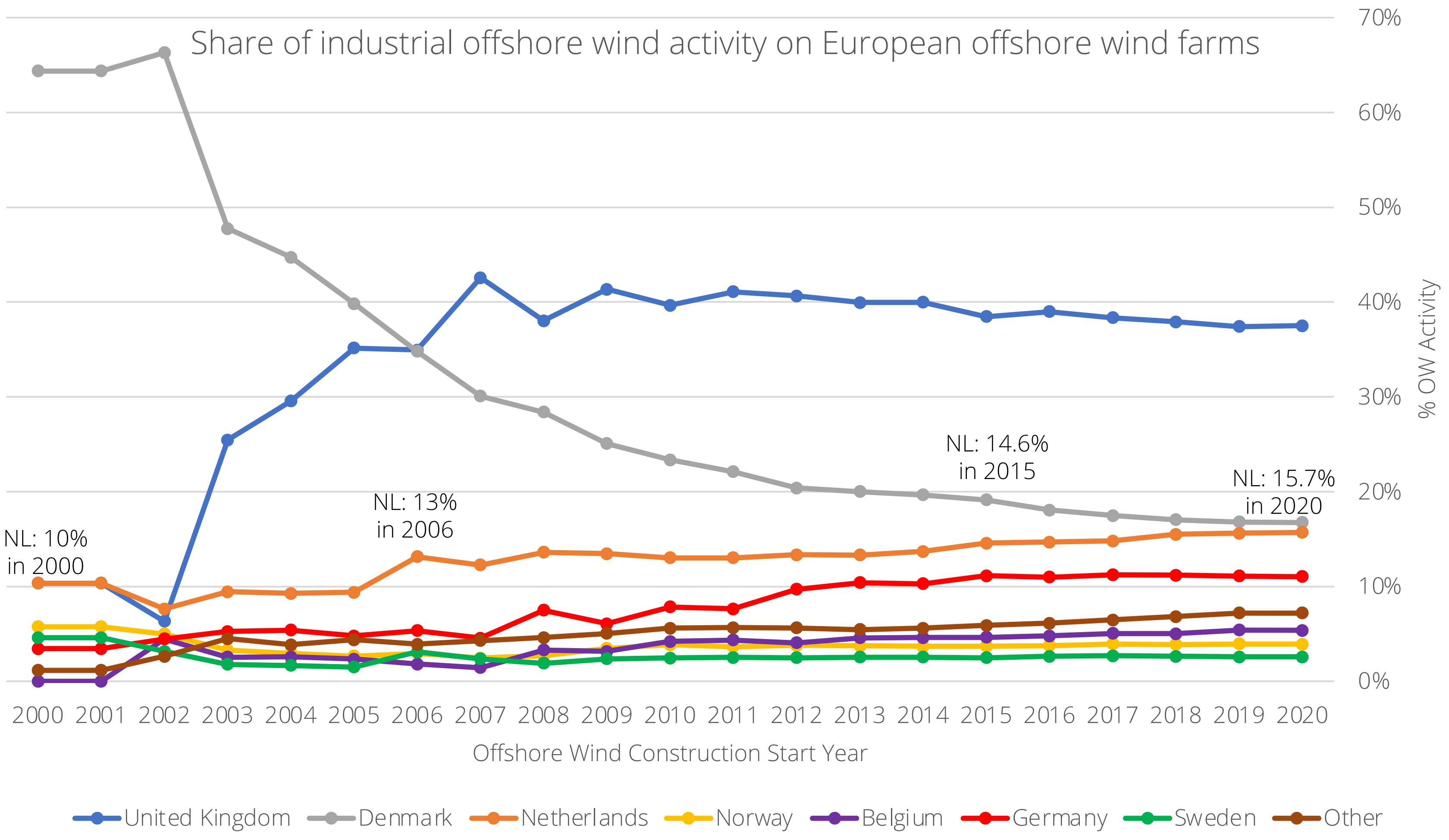
What is offshore renewable energy?

Offshore renewable energy – and particularily offshore wind – will be the cornerstone of the Dutch energy transition, accounting for roughly 2/3 of all renewable energy production by 2050, with the rest coming mostly from onshore wind and solar. According to the Northsea Energy Outlook (2020), there will be an estimated 38-75 GW of total offshore installed capacity by 2050, up from ~2.5 GW in 2021 and 11.5 GW in 2030.

- **Classic offshore wind – the current system**
  - Three-bladed, upwind turbine on a fixed-bottom monopile foundation, installed using jack-up vessels and monopile hammers
- **Potentially disruptive future offshore wind**
  - Floating foundations
  - Non-monopile fixed-bottom foundations (e.g., gravity-based float-and-sink)
  - Disruptive turbines, ex. two-bladed, downwind turbines; hydraulic turbines; vertical-axis turbines, etc.
- **Potentially disruptive alternative maritime renewable energy technologies**
  - Tidal turbines: fixed-bottom and kite-tidal turbines
  - Wave turbines
  - Blue energy (salt-fresh water salinity gradient)
  - Airborne systems (kites)

Offshore wind industrial activity

- The Dutch industry has captured nearly 16% of all industrial activity on European offshore windfarms (based on number of contracts)
- For a relatively small country by population, it participates very strongly in the offshore wind industry
- Currently, more than 100,000 people are employed in offshore wind in Europe, which will increase to 350,000 by 2030 (Buljan 2021)
- This means that there is a lot to gain
- But there is also a lot to lose



Source: 4C Offshore Wind (2019). Data is based on number of contracts for all European offshore windfarms

Threats and opportunities to industries

Disruptions *can be one of the biggest threats – and greatest opportunities – to an industry. These changes can be placed into three categories relative to the current functioning of the industrial sector*

3 major potential changes to industries

1. **Threatening disruptions** replace existing systems and industries in which **we participate**. There is a high risk because there is a lot to lose. For example, the Netherlands has a strong share of the monopile foundation industrial segment for offshore wind, which means that a disruptive foundation would have a major impact on the Dutch offshore renewable energy industry
2. **Non-threatening disruptions** replace existing systems and industries in which **we do not participate**. It is a no-risk opportunity because there is not much to lose, but there is also opportunity to capture new value. For example, the Netherlands has no major wind turbine producers; therefore, if a disruptive wind turbine entered the market, it would not disrupt the Dutch industry, but it also means that there is a potential opportunity to capture a new industrial segment
3. **Complementary additions** add to existing system, but do not replace it: it is a no-risk opportunity, but there is potential to miss out. For example, power-to-x (green hydrogen or ammonia) could provide means to store excess renewable energy; it cannot disrupt offshore wind, but can complement intermittent renewable energy and provide new potential economic growth pathways

Major shifts in industries following disruption

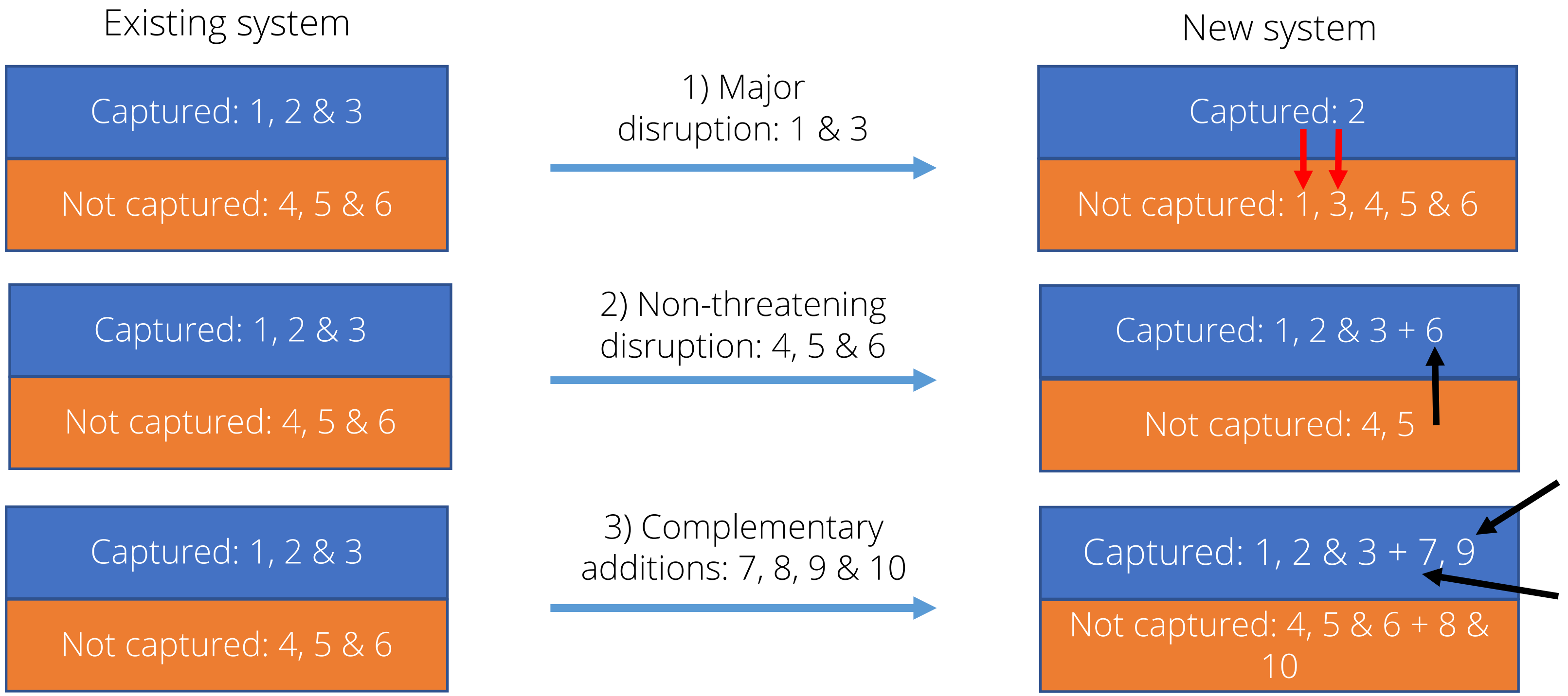
In this hypothetical system, industrial segments *1, 2 & 3* are captured by the domestic industry. Segments *4, 5 & 6* are captured by foreign industries.

1. In the event of a major disruption to segments *1 & 3*, the domestic industry loses them to foreign industries, leaving only *2* to be captured domestically. This is a net loss.

2. In the event of disruptions to *4, 5 & 6*, the domestic industry has successfully captured *6*, thereby adding it to its portfolio of expertise. *4 & 5* are still captured externally. This is a net gain.

3. When there are complementary additions, both domestic and foreign markets have a chance to capture new opportunity. In this example, the domestic industry has captured *7 & 9* and foreign industries have captured *8 & 10*. This is a net gain.

What happens when there are major changes to industries



The numbers represent hypothetical segments of an industry captured within or outside of the domestic industry

Summary of threats and opportunities

	What	Degree of risk	Potential to capture new opportunities	Explanation
Major disruptions	Potential disruptions replace existing technologies and industries in which we participate	High	Medium	Since these are disruptions to the existing system in which we participate, there is a lot to lose if the Netherlands is not careful. With the right strategy, there is potential to capture these disruptions internally due to existing experience, competencies and relatedness
Non-threatening disruptions	Replaces existing technologies and industries in which we do not participate	Low	Low-medium	There is a low risk because these disruptions are not in a field in which the NL participates. There is nothing to lose, but it may be difficult to capture these disruptions because there is limited experience. If captured, it is a big win
Complementary additions	Adds to existing system, but does not replace it: no-risk opportunity	Low	Low-high	While these may be major changes to the existing system, they may only serve niche or specific markets or complement the existing system. It will not replace the system as it currently is. There is a relatively low risk, but there may be opportunities to benefit from these additions. Some additions may be easier to capture than others

What makes the offshore renewable energy sector resilient?

An innovation eco-system focuses on the continual renewal of industrial sectors, which is essential to addressing changing circumstances. Without renewal, the system becomes vulnerable to external shocks and disruptions. It is necessary to stimulate continuous renewal with the ambition to ensure long-term survival and growth. Often, innovation eco-systems focus on the national or regional level, such as the Dutch offshore renewable energy sector.

"Regional resilience is conceptualized not just as the ability of a region to accommodate shocks...but it is extended to the ability of regions to reconfigure their socio-economic and institutional structures to develop new growth paths"
(Boschma 2015, pg. 734)

Variety

"Industrial variety in a region spreads risks and can better accommodate idiosyncratic sector-specific shocks" (Boschma 2015, 736)

Variety is an essential component of a healthy innovation eco-system because it leads to more potential combinations and therefore prospects and opportunities.

When variety is not in balance, the entire innovation eco-system – often measured at the national or regional level – may be threatened, meaning it is less resilient to shocks and ability to foster growth.

We focus on three types of variety to assess the health of the innovation eco-system for offshore renewable energy: **blind variety, targeted variety** and **market variety.**

Three types of variety

1) **Blind variety:** more variety → more capabilities and recombination options → more potential opportunities. Greater variety will increase the likelihood of being able to adapt to unpredictable disruptions (Frenken, Hekkert & Godfroij 2004).

2) **Targeted variety:** targeted capability development → capture specific opportunities. Industry experts evaluate promising technologies that may disrupt the existing system. Tailor innovation to promising technologies and explicitly try to capture them.

3) **Market variety:** active in a diverse range of countries and a diverse range of market segments insulates against disruptions to specific markets. Political uncertainty or technological favoritism may cause markets to disappear or stagnate.

Methods

Data

To opperationalize our three types of variety, we actuate a number of different data sources

- RVO R&D project database (149 projects since 2010)
- 34 interviews with Dutch offshore renewable energy stakeholders
  - Incumbents
  - Established SMEs
  - Young companies/startups
  - Networking orgs., incubators, accellerators, etc.
  - Government
- 4C Offshore Wind database (April 2019)
- Industry reports (4C, IEA, NORWEP, DNV GL, IRENA, Dutch reports, etc.)
- Industry news (4C, Offshore Wind, etc.)

Step 1 – coding innovation activities: Sustaining versus disruptive innovation

To determine whether the offshore renewable energy sector is resilient, the first step is to understand what types of activities are taking place. Innovation activities are broken into **sustaining incremental, sustaining radical** and **disruptive innovation.** Both incremental and radical innovations are better versions of the existing system. Disruptive innovations initially perform worse than the dominant design, but have the potential to perform better following a process of trial-and-error and cost reduction.

	What	Key actors	Ability of actors to adapt	Threat to	Opportunity for	Examples
Sustaining incremental innovation	Improves current design & production through small steps to strengthen the performance from what was previously available	Incumbents; established SMEs	High	Disruptive startups	Incumbents; established SMEs	Bigger monopiles; longer turbine blades; optimized windfarm layout
Sustaining radical innovation	Major 'leapfrog-beyond-the-competition' changes that still improve the current system and paradigm	Incumbents; startups that fit dominant design	Medium	Disruptive startups	Incumbents; supportive startups	Slip-joint (replaces transition piece); hydrogen powered vessels; quieter monopile hammers
Disruptive innovation	Disrupts and redefines technologies by introducing products and services that currently have a lower price-quality performance. It is a paradigm shift and may lead to industry shake-out	Startups	Low	Incumbents	Startups	Floating foundations; disruptive turbine designs; blue energy; float-and-sink foundations

Christensen (1997); Utterback (1994)

Step 2 – categorizing innovation activities

Next, we group all innovation projects into 1 of 3 technology readiness level (TRL) categories: ‘**Discovery**’ (TRLs 1-3), ‘**Development**’ (TRLs 4-6) or ‘**Demonstration**’ (TRLs 7-9)

Then, we combine **‘sustaining incremental’** and **‘sustaining radical’** innovations because these innovations reflect maintaining the current industrial paradigm

This creates 6 innovation categories:

Sustaining discovery, development and demonstration

Disruptive discovery, development and demonstration

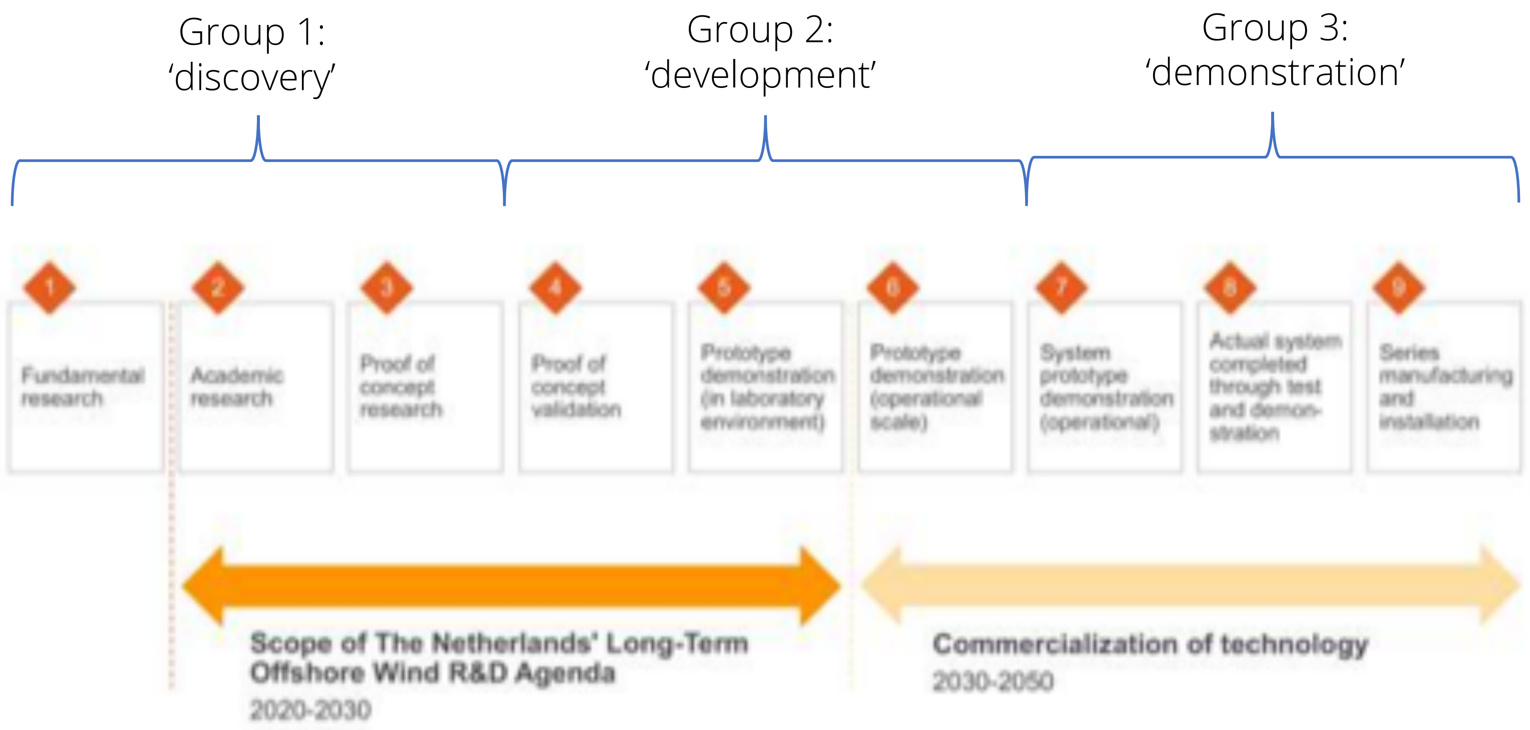


Figure 1 – TRL[1] scope of the technological content of the R&D agenda

TKI Wind op Zee (2019)

Step 3 – assessing blind variety

Blind variety relates to creating a wider range of innovation activities without preselecting projects or pathways. There should be a well-balanced portfolio of sustaining and disruptive blind innovation

We measure the balance of sustaining versus disruptive R&D by evaluating the distribution of the six innovation categories mentioned above by **total number of projects** and **total amount of funding** allocated for each category

Then, we assess the available subsidy instruments, TRL focus and main themes for the offshore renewable energy innovation programs. This demonstrates how R&D funding is allocated and what the priority themes are

Next, we highlight the key challenges innovators face in trying to improve their novel technologies by analyzing interviews with startups

By evaluating these criteria, we determine whether there is a sustainable balance between disruptive and sustaining innovations to ensure a resilient industry or whether there is unsustainable lock-in to current technologies

Step 4 – assessing targeted variety

Targeted variety focuses on specific technological trajectories. The emphasis is on the focus of R&D projects and whether they align with these trajectories and with the existing competencies from the industry. Hence, we can determine whether we target threating or non-threatening disruptions or complementary additions

1. We identify potential disruptions based on expert opinion through industry reports
2. Based on the R&D project database, we identify what specific variety the Netherlands focuses on and what is largely absent
3. We also identify the phase of development (TRL range) for these projects to determine how close these innovations are to commercial-scale readiness
4. Therefore, we assess whether the innovations occuring in the Netherlands are in line with potential disruptions
5. Finally, we assess whether these innovations relate to existing expertise or whether they are outside the industrial scope

Step 5 – assessing market variety

Market variety is dependent on a balanced distribution of market penetration in existing domestic and foreign markets as well as successfully entering emerging markets. It is also about the diversity of the industry and industrial segments

First, we evaluate participation in existing markets by assessing the relative distribution across countries. Participation can be measured through all Dutch contracts won in different countries

Then, we evaluate market penetration per sector. Is market pentration concentrated on only a few sectors or is it diverse? This is measured by assessing the share of contracts won by Dutch companies per industrial segment, such as vessels, foundations, etc.

Next, we evaluate access to new markets: do Dutch companies successfully win contracts in emerging markets? This is measured through industry reports, newsletters and interviews

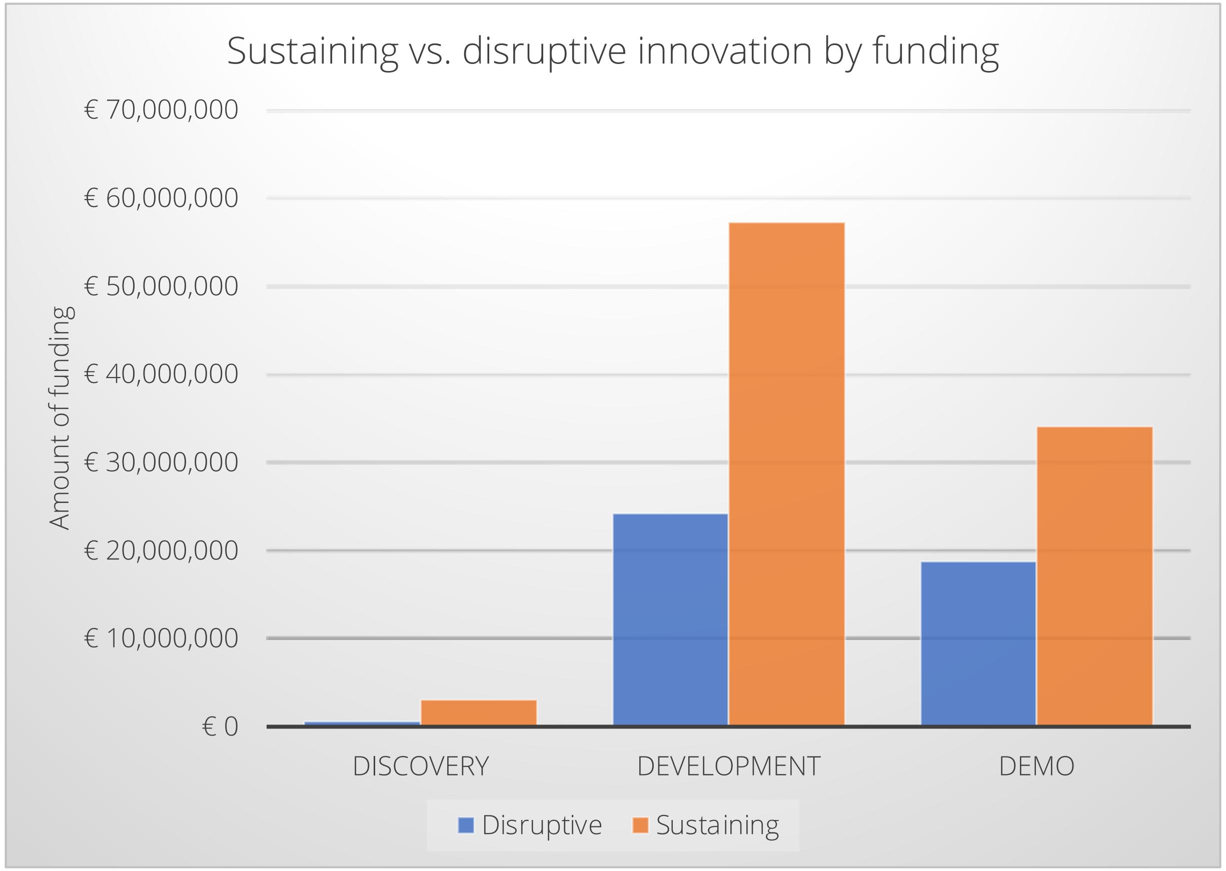
Finally, we evaluate whether Dutch companies have participated on disruptive projects and in what capacity. This is also measured through industry reports, newsletters and interviews

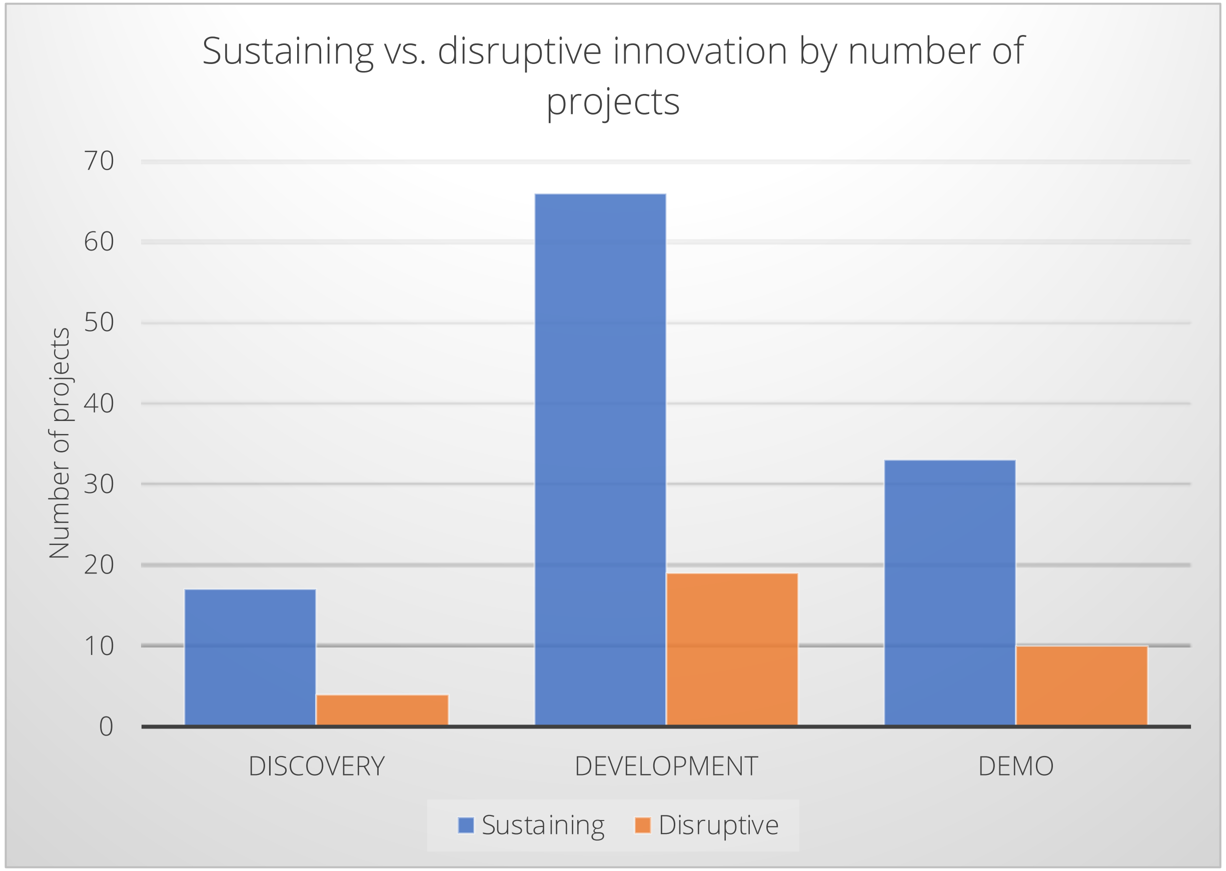
Results

Blind variety

Sustaining versus disruptive innovation

Sustaining innovations receive 5-6 times more government support than disruptive innovations, both in funding and number of awarded projects





How is current government sponsored R&D funded and where does it go?

"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" (Dutch disruptive startup)

- There is support for high-TRL demonstration projects (HER/RER+ and DEI+ schemes).
- The subsidy rules require significant **in-kind funding** from the private sector (often ~50%) to access these subsidy instruments (RVO 2019)
- It is extremely difficult to receive support from the private sector if the innovation may put the private sector out of business
- The Borselle V demonstration zone **only has sustaining innovations** (monopile foundations, slip-joint, regular turbine, improved scour protection)

"Borssele V [offshore wind demonstration zone]… It's not really an innovation site. It's ridiculous. This Borssele V was a complete fiasco" (Dutch disruptive startup)

Subsidy instruments

The government stimulates activities that fall within the TKI Wind op Zee innovation program by means of subsidies. There are different sort of subsidies available for various types of research, applicants, and themes.

TRL Range	Cost Reduction and Optimisation	Integration in the Energy System	Offshore Wind and the Environment
Low TRLs: Discovery	NWO subsidies for academic research - Programme Knowledge and Innovation Convenant - Dutch Research Agenda	NWO subsidies for academic research - Programme Knowledge and Innovation Convenant - Dutch Research Agenda	NWO subsidies for academic research - Programme Knowledge and Innovation Convenant - Dutch Research Agenda
Mid TRLs: Development	- Mission-driven Research, Development and Innovation subsidy scheme (MOOI) (Industrial and experimental research) - Renewable Energy Scheme	- Mission-driven Research, Development and Innovation subsidy scheme (MOOI)	- Mission-driven Research, Development and Innovation subsidy scheme (MOOI)
High TRLs: Demonstration & Deployment	- Renewable Energy Scheme - DEI+ 2020	- DEI+ 2020	- DEI+ 2020

TKI Wind op Zee (2020)

Key blind variety takeaways

R&D program lines are generally well-funded

The programs focus on blind innovation because they do not target specific technologies

However, the guiding principles of ‘cost reduction’ and ‘optimization’ directly prioritize sustaining innovation

Most R&D projects – by number and financial value – are sustaining in nature

Very difficult for disruptive startups to get financed because they are required to find in-kind funding from the private sector to access public funds. Private companies are not likely to invest in startups that have the potential to put them out of business

The Borssele V demonstration farm only includes sustaining innovations developed by incumbent actors and not disruptive innovations developed by startups (Durakovic 2021)

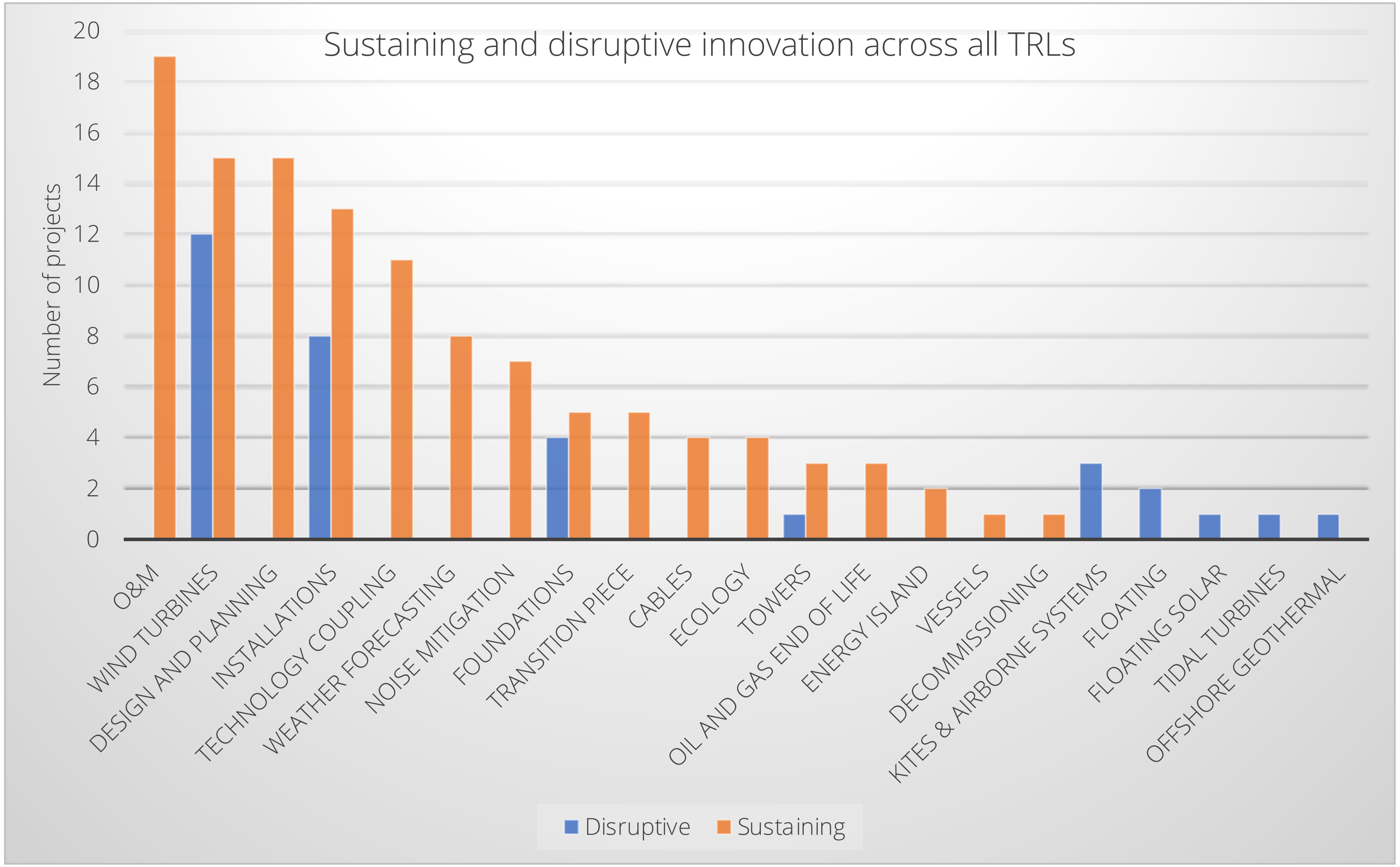
Targeted variety

Potentially disruptive technologies

Industry analyses of disruptive offshore renewable energy are commonly broken down into wind turbines, offshore wind foundations, installations, floating offshore wind and other maritime renewable energies technologies. The examples here are just some examples of disruptive innovations per category (DNV GL 2020; Irena 2016; NORWEP 2019)

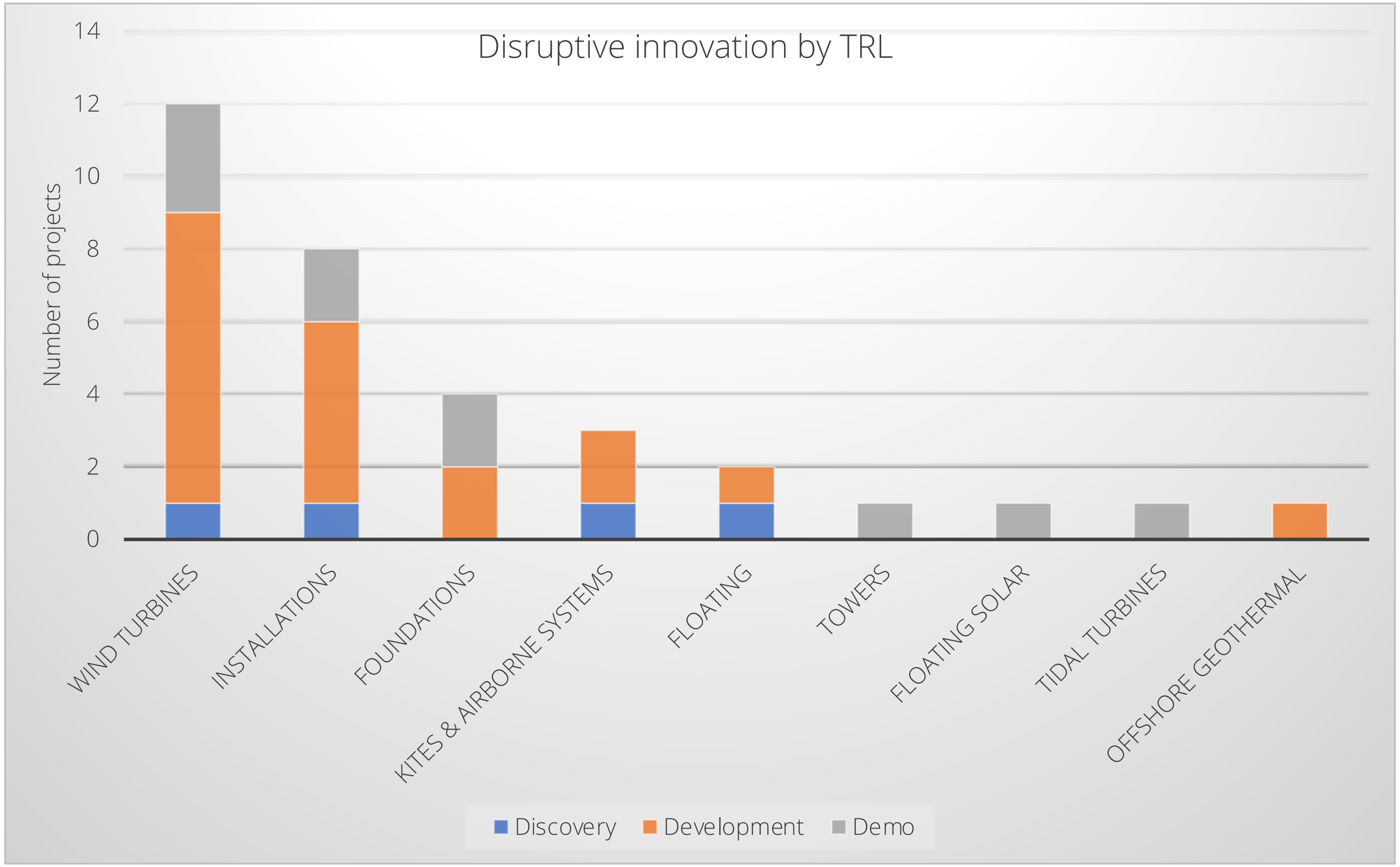
- Wind turbines
  - Two-bladed, downwind
  - Hydraulic, pump-based
  - Vertical-axis turbines
- Foundations
  - Gravity-based
  - Float-and-sink
  - Suction buckets
- Installations
  - Motion compensation
  - Certain disruptive foundations
- Floating offshore wind
  - Spar buoy
  - Semi-submersible
  - Barge
  - Tension-leg platform
- Alternative maritime tech.
  - Wave
  - Tidal
  - Kites
  - Blue energy

Sustaining innovations



- Most sustaining innovations go into wind turbines, installations, O&M, design & planning, technology coupling and noise mitigation
- Example: the government awarded 5.8 million Euros for two monopile installation projects in 2021 (Buljan 2021; Skopljak 2021)
- Example: the industry is investing in 'TP-less' monopile to turbine tower connections: major sustaining innovation (Durakovic 2021)
- Less sustaining innovation is focused on cables, ecology, towers and decommissioning

Disruptive innovations



- Most disruptive innovation goes into radical wind turbines
- Significant disruptive innovation for installations
- However, most disruptive installation R&D only focuses on dynamic positioning/motion compensation
- If motion compensation succeeds at disrupting the industry, it could be captured domestically
- If other disruptive installation methods are more successful, there is a big risk to the Dutch installation industry
- There are four disruptive foundation projects, however, the two demonstration projects occurred in the UK & Denmark

Attention to targeted variety

- Most R&D goes into sustaining innovations, such as improving the monopile, as explained by a radical foundation startup
- Maritime renewable energy companies struggle to get support and funding from the Netherlands because there is no explicit program line or government agenda
- Most of their subsidies come from European funds

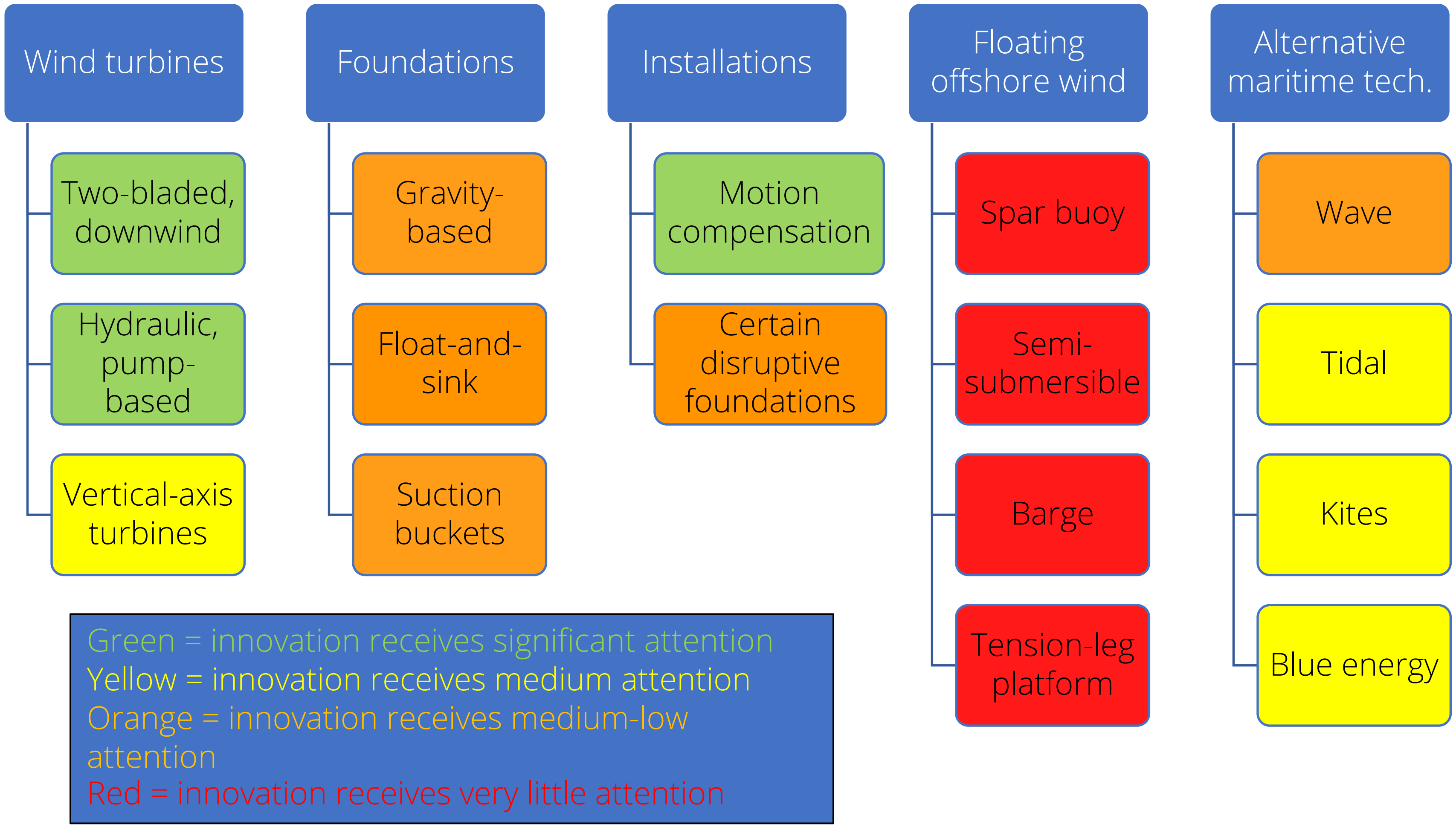
"[They] decided a thousand years ago to become a niche monopolist in the monopile offshore wind farm business. So they're not interested in a product like [ours]. They're only interested in a type of foundation which involves their vessels. They will actively try to keep everybody out. Even though they're big and they can afford it, they stick to their own R&D, which is incremental in order to stick to that market" (Disruptive startup)

"At this moment, we get very few subsidies from the Netherlands" (Maritime renewable energy startup)

"Maritime renewable energy is just not on the government agenda" (Maritime renewable energy startup)

Attention to potentially disruptive technologies

- The government gives tremendous attention to radical wind turbines. This is a sector that it does not currently participate in
- Disruptive motion-compensated installations receive attention
- Disruptive fixed-bottom foundations receive some, but not a lot, of attention
- They may also disrupt installation techniques
- Alternative maritime technologies receive some support, but most funding comes from the EU
- Floating wind receives almost no attention



Analysis of targeted variety

Disruptive targeted variety

- **Wind turbines:** biggest disruptive targeted innovation focus
- **Disruptive fixed-bottom foundations:** the two high-TRL demonstration projects were developed by established companies (not startups) and tested in the UK and Denmark (not the Netherlands)
- **Installations:** there is a strong focus on dynamic-positioning/motion compensated installations, removing the need for jack-up vessels
- **Floating:** almost no innovation focus on floating offshore wind
- **Alternative maritime technologies:** there are several scattered projects and a few startups. However, there is no government strategy or agenda. A new agenda is expected by the end of 2021.

Sustaining targeted variety

- **Installations** and **O&M** receive massive R&D support. They are directly linked to improving current offshore wind practices and tie into the 'cost-reduction' subsidy instrument program line
- **Weather forecasting** and **design & planning** receive significant support and meet the program line criteria for 'optimization'
- **Noise mitigation** from quieter monopile hammers or alternative pile-driving techniques benefit from R&D subsidies & help the incumbent system reduce traditional noise mitigation costs
- **Incumbents keep disruptors out** by not providing in-kind funding & lobbying the government to support their research agenda

Key targeted variety takeaways

Significant disruptive innovation targeted to wind turbines, which the Netherlands does not have a share in. Massive investments and support are required across all TRLs and upscaling to capture such a position

Monopiles are currently the dominant design choice and receive massive amounts of incremental innovation support

Some support for disruptive foundation designs, but more limited at high TRLs; high reliance on foreign governments

Installation disruption (via motion-compensation) may be captured domestically. Installation disruption due to disruptive foundations is a threat

Limited support for tidal & wave turbines. Occasional demonstrations, but no consistent trajectory

Almost no floating offshore wind innovation

Targeted variety weaknesses

Little support to develop floating foundations because it is only useful for the export industry and not the Dutch energy transition → potential to miss out; threat to deeper fixed-bottom markets (~50-70 meters)

Unlikely to capture markets for disruptive fixed-bottom foundations without more support → **threat** because other countries may capture the benefits of disruptive foundations and may also threaten the installation industry

Extensive opportunities for tidal and wave turbines that are not being capitalized upon because there is limited energy potential (except as a small, predictable energy source) in the Netherlands. There is some R&D support, but no government agenda → **missed export product opportunity**

Limited follow-through to capture disruptive turbine market. Wind turbines receive support, but there is limited support for upscaling and full-scale demonstration projects

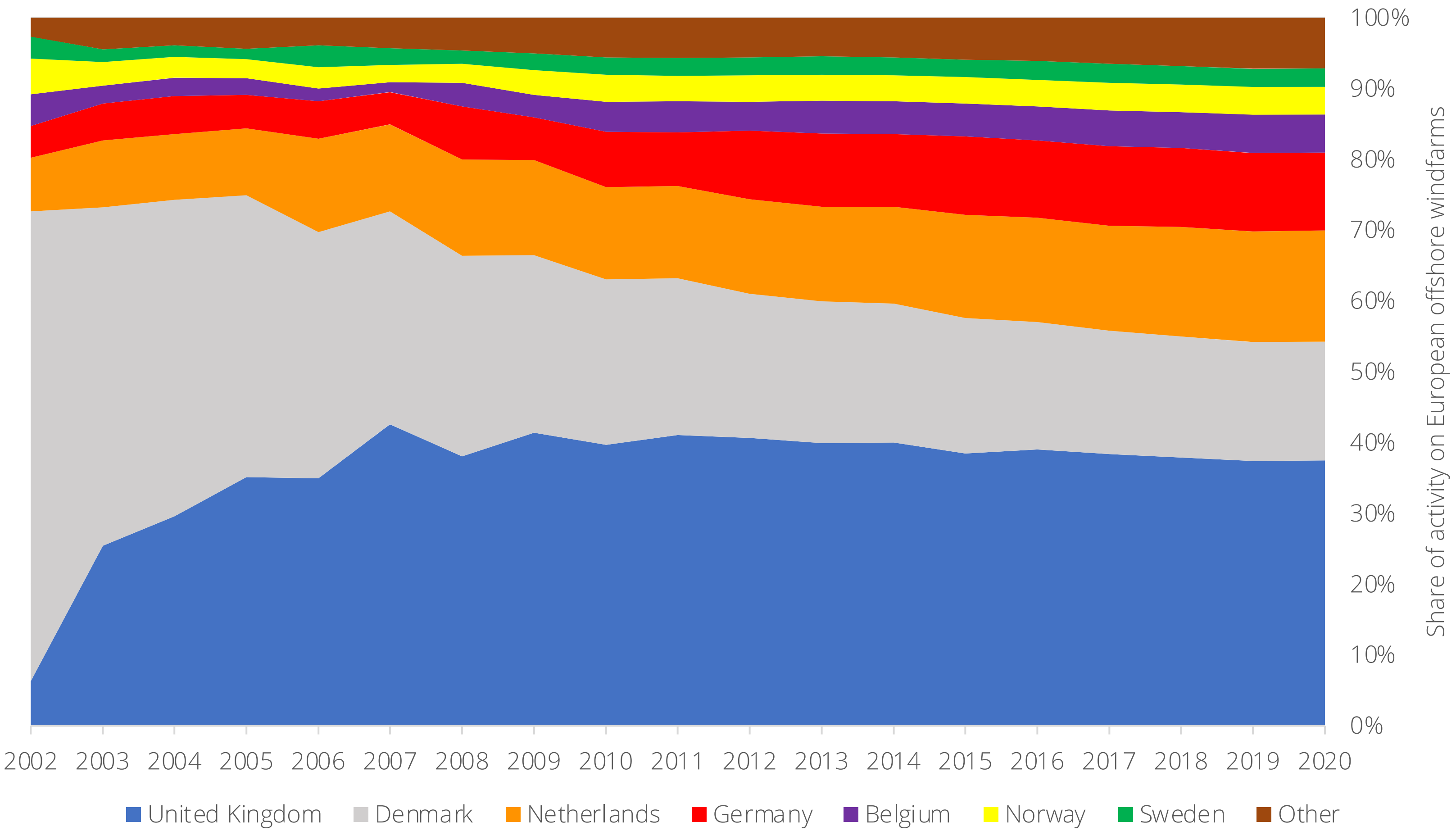
High degree of lock-in for existing expertise in foundations and installations. The Netherlands excels in these industries, which means that it is at risk of being disrupted

Market variety

Offshore wind market capture

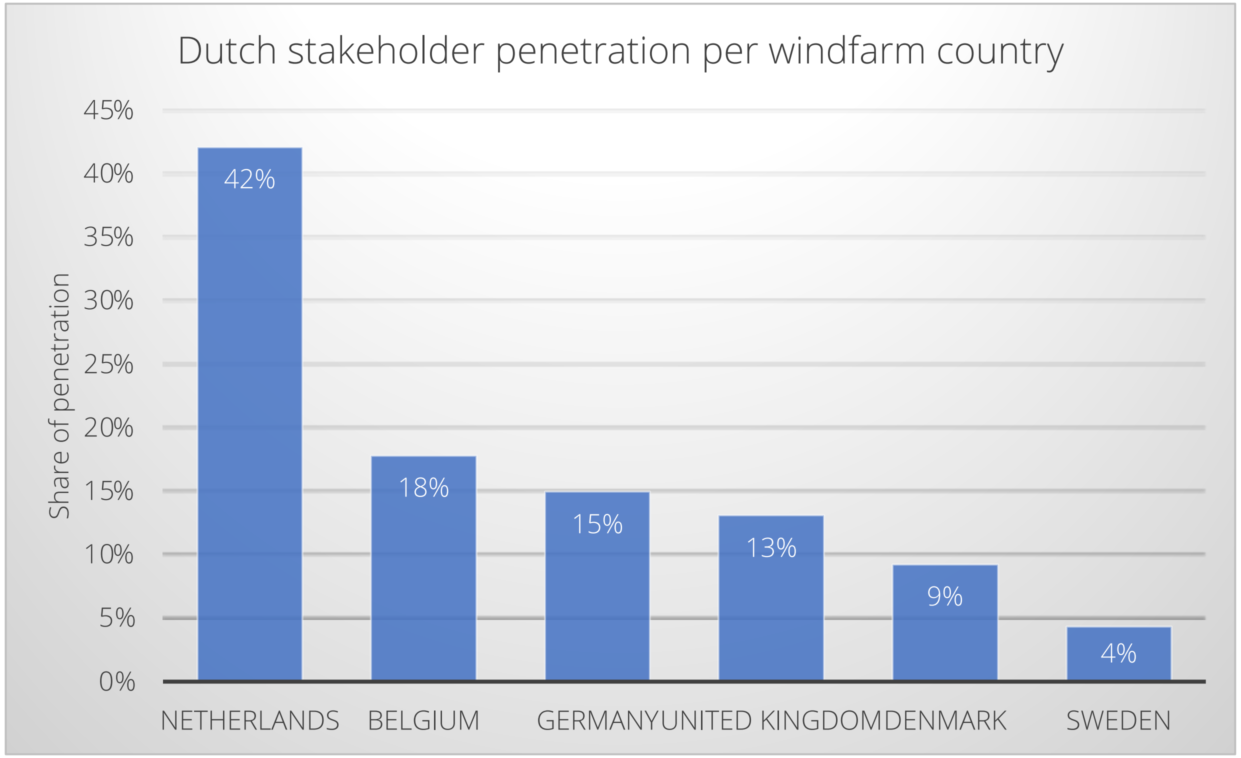
- The Netherlands has increased its participation on European offshore windfarms from 10% in 2000 to almost 16% in 2020
- For a small country by population, it participates very strongly in the offshore wind industry
- With over 100,000 jobs in Europe in 2020, and over 350,000 by 2030, the economic opportunity is tremendous
- There is more to gain, but there is also a lot to lose

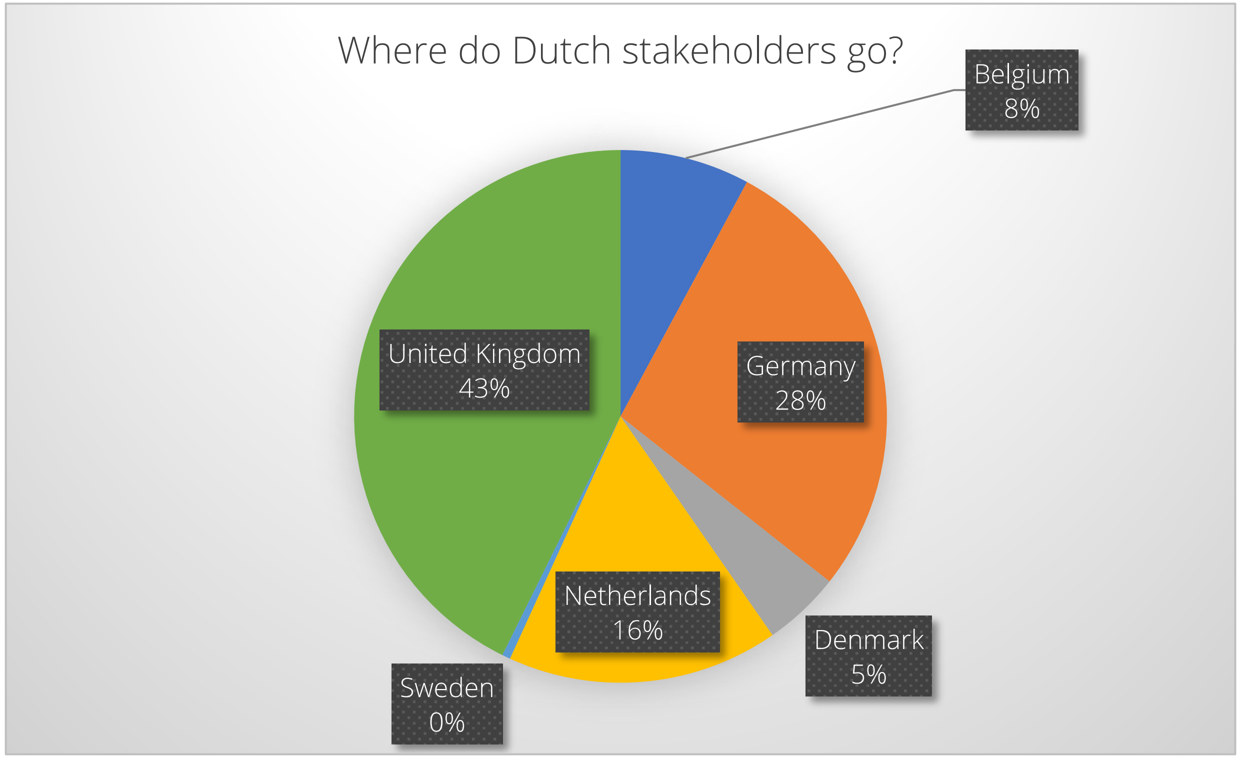
Share of offshore wind market capture on European offshore windfarms



N.B. Source: 4C Offshore Wind (2019). Data is based on number of contracts for all European offshore windfarms

Breakdown by major European markets





The Dutch average about 16% market penetration in the 6 main European markets. The highest penetration is at home, but also in the biggest offshore wind markets: the UK, Germany, Belgium and Denmark. As a share of total activity, most Dutch activity goes to the UK, followed by Germany and then the Netherlands. Recent news reports indicate that Dutch companies have successfully signed contracts in the USA, Vietnam, Taiwan, South Korea and Japan, amongst others.

Accessing new and existing markets

There is a high share of Dutch activity on Dutch and international wind farms → **high degree of market resilience** at the country level

The Netherlands has **won contracts** in many emerging offshore wind markets, including the USA, Taiwan, Vietnam and Japan

These concentrate on classic offshore wind technology in the sectors that the Netherlands already excels in

Strong domestic roadmap for offshore wind that supports green growth

"We need to also spread out of Europe. We need to go to South East Asia, there needs to be a proper scheme in the US without, for instance, the Jones' Act. Trade barriers and stuff. All those things need to move in order to make sure that this will be a global business" (Dutch incumbent)

"Because in the end the US is looking to Europe, even in Taiwan they're now looking to Europe saying, 'Wow, they're doing it cheap. We also want to do it cheap'. You cannot do everything, you also need to have the knowledge that we have built up here in Europe. You need to transfer it to either the US or Taiwan. Or else you will not be able to do it cost competitively" (Dutch incumbent)

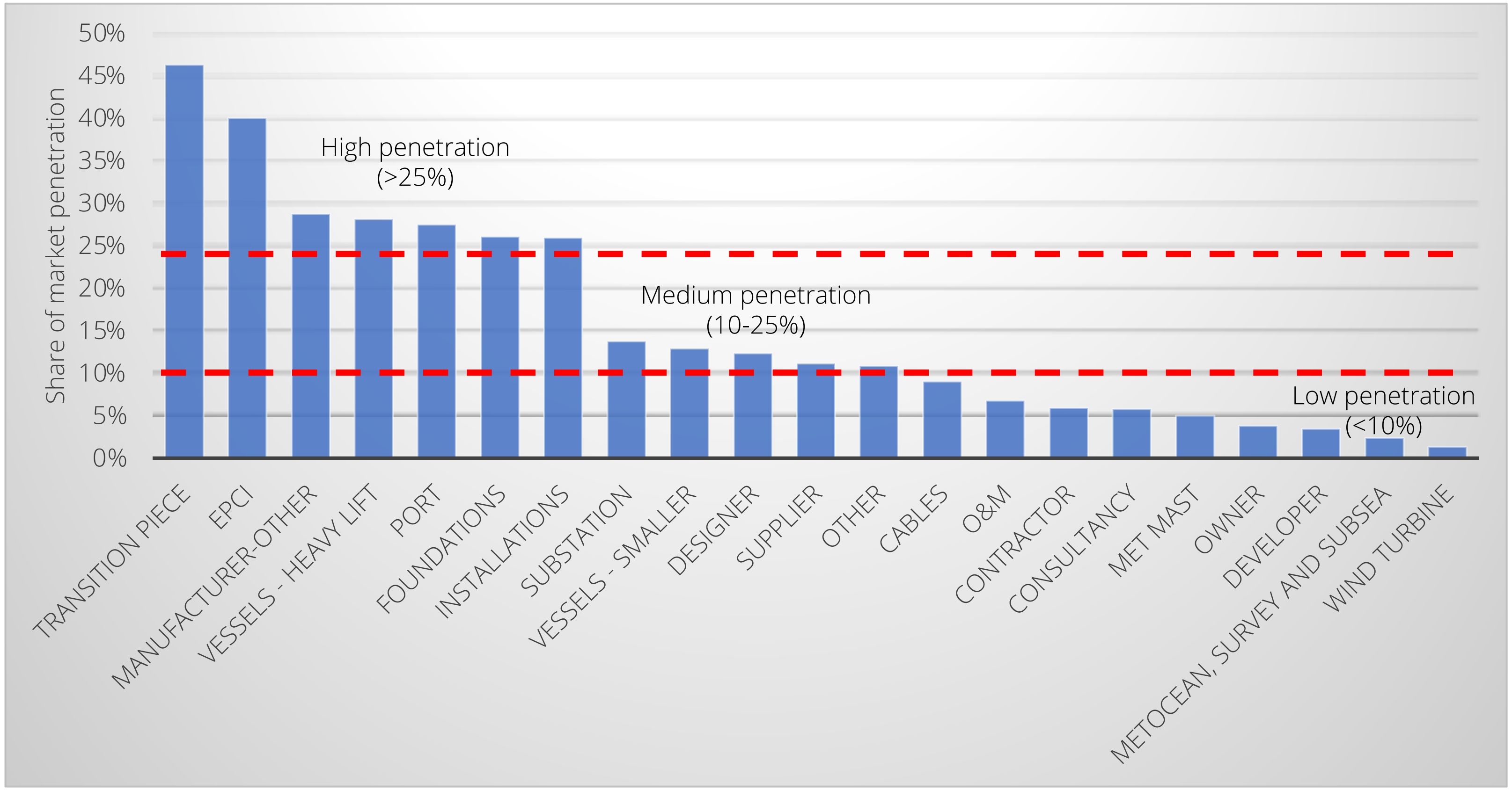
"I think the policy they've now established, with every year around 1 GW of tendering, that's beneficial for the Dutch companies in how to attract offshore wind and how to be one of the front countries. And...the Dutch government is being invited by other countries about giving insight into how they've done this policy setup and why it's working" (Dutch incumbent)

Key takeaways from country-wide market access

- Strong penetration in existing markets for classic offshore wind (~16% on all European offshore windfarms)
- Powerful incumbents with decades (or centuries) of experience, well funded R&D departments, extensive networks
- Successfully accessing new markets for classic offshore wind (Taiwan, Vietnam, USA)
- Will likely penetrate new European markets (Poland, France)
- Strong variety of markets: if one market has a ‘down year’ (such as Germany in 2020), the Dutch industry is diverse enough to withstand these shocks
- Vessels face protectionist challenges with the Jones’ Act in the USA and local content regulations in South East Asia → not a threat, but may limit opportunities

Market penetration for offshore wind by sector

Dutch market penetration in Europe by stakeholder type



N.b: 'vessels heavy lift' includes vessels for turbine, TP, foundation, cable and substation installation; 'vessels – smaller' includes vessels for personnel, O&M, etc.

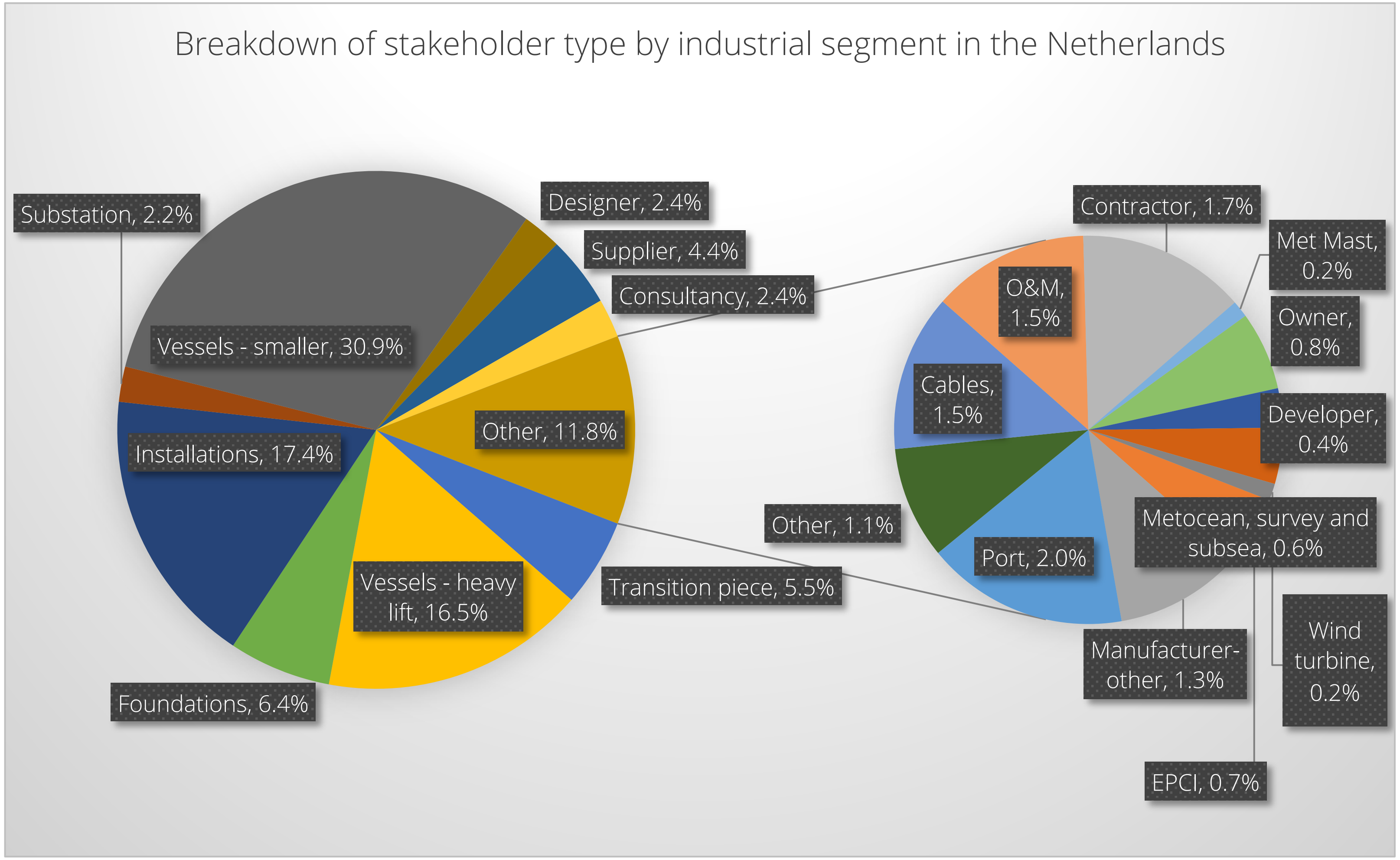
The chart shows that the Dutch have very **high penetration (>25%)** in installations, vessels – heavy lift, foundations, transition-pieces, ports, EPCI and manufacturing diverse components (other)

There is **medium penetration (10-25%)** in substations, vessels – smaller, design, suppliers and other activities

There is very **minimal penetration (<10%)** in wind turbines, cables, developer, consultancy and ownership

Source: 4C Offshore Wind (2019). Data is based on number of contracts for all European offshore windfarms

Diversity of Dutch expertise in offshore wind



- The Dutch offshore wind industry is mostly composed of **installations** (>17%) and heavy lift and smaller **vessels** (>47%). This means most contracts are from a very narrow industrial range
- **Foundation** and **transition-piece** manufacturing (~12% of contracts, combined) are high in value, employ many workers and capture a large market-share (see previous slide), but contain fewer contracts
- It is a **highly concentrated industry**

N.B. Source: 4C Offshore Wind (2019). Data is based on number of contracts (not monetary value) for fully commissioned, partial-generation and under construction European offshore windfarms

Market penetration for disruptive technologies

Floating: Royal Boskalis (incumbent) transported and installed the foundations and turbines on the Scottish Kincardine windfarm; the Port of Rotterdam received and shipped the foundations with pre-installed turbines (Durakovic 2020)

Suction-bucket foundations: SPT Offshore (established oil & gas SME) designed suction-bucket foundations and supported their installation on the Aberdeen Offshore Windfarm & 2 windfarms in China (SPT Offshore 2018; Skopljak 2021)

Gravity-based float-and-sink foundations: Royal BAM (incumbent) received a construction contract by EDF (France) to build five gravity-based float-and-sink foundations that were installed at the Blyth Offshore Demonstrator in 2017 (Royal BAM 2017)

Tidal turbines: Tocardo BV (tidal turbine startup) was sold to a British company (Unen 2020)

Key takeaways from market penetration by sector

- Industry is concentrated on vessels and installations, which are often linked (installer owns the vessels). Combined, this accounts for **64% of all Dutch activity,** indicating a concentrated and homogenous industry (not diverse)
- Monopile and transition-piece manufacturing are very strong and high-value
- Some industry penetration for floating offshore wind from the installation sector, which uses existing installation capabilities
- Established companies can physically construct disruptive foundations if contracted and properly financed
- The economic benefits from developing other maritime renewable energy technologies are mostly in selling to foreign companies
- There is a high degree of lock-in, indicating potential risks in the event of disruption

Recap weaknessess: vulnerabilities

Transition-piece and monopile manufacturing are vulnerable to disruption if new foundation types become the dominant design

Heavy-lift jack-up vessels and installations may be threatened if alternative installation techniques become the standard

EPCI and ports are not likely to disrupted, but rather face market competition as offshore wind expands

Wind turbines are not a threat as there is little current penetration, implying potential opportunities for new industry capture

Summary of results

Threats, missed opportunities and resilience

Existing threats to	Potentially missed disruptive opportunities	Potentially captured disruptive opportunities	Potentially captured sustaining radical innovations	Resilient sectors
Foundation industry	Floating foundations	Dynamic-positioning installations[2]	Quieter monopile installation techniques (hammers, vibration, etc.)	Existing and new fixed-bottom markets
Jack-up vessels[1]	Disruptive fixed-bottom foundations (gravity-based, float-and-sink)	Disruptive fixed-bottom foundations (suction-buckets)	Slip-joint	Installations, incl. floating, dynamic positioning, cables, etc.[2]
Transition-piece industry	Tidal and wave turbines[4]	Radical wind turbines[3]	Technology coupling	Vessel supply
Monopile hammer industry	Kite turbines	Tidal and wave turbines[4]	Hydrogen powered vessels	Geological surveying
	Deep-water markets	Blue energy (salt-fresh water salinity gradient)		Consultancy

1. The vessel and installation industries are strong, including some potential capture of the floating market. Depending on technological developments, jack-up vessels may become entirely obsolete or continue to be used for some market segments, but less than today
2. Dynamic positioning/motion-compensated installations may disrupt the installation segment and be captured domestically
3. Many startups around the world develop radical wind turbines, but face major hurdles to disrupt classic wind turbines & 'the big three' (Siemens-Gamesa, Vestas & GE Renewable Energy)
4. Tidal and wave turbines score in the middle-ground. There is some R&D, technological demonstration and market diffusion, but also limited government support or appetite for full commitment

Recap: strengths

- Classic offshore wind: huge market, huge industry
- Ambitious 38-75 GW domestic roadmap for classic offshore wind
- Strong international market penetration for classic offshore wind
- Well funded R&D and networking for sustaining innovation
- Medium-well funded R&D for disruptive innovation at low TRLs
- Some market/export penetration for emerging disruptive offshore technologies (suction-bucket foundations, tidal turbines, floating foundation installation)

Recap: weaknesses

- Industry and government very locked into classic offshore wind
- Weak high-TRL support for disruptive offshore wind
- Weak high-TRL support for disruptive maritime renewable energies (tidal, wave)
- Weak full-scale demonstration support or protected niche-space for startups
- Weak legitimacy beyond ‘classic offshore wind’
- Energy policy on offshore wind industry in the Netherlands focuses on carbon mitigation
- No industrial policy or export strategy

Recommendations

Broad recommendations

- Stimulate long term investments in sustaining and disruptive technologies
- Encourage disruptive R&D in addition to sustaining innovations
- Promote full-scale demonstration of sustaining and disruptive innovations
- Accelerate the diffusion of disruptive innovations
- Invigorate the entire innovation eco-system for offshore renewable energy
- Develop an industrial policy without compromising the 2050 carbon mitigation targets

A 6-step plan

1) Develop a concrete 2030-2050 roadmap for offshore wind

- Like the 2023 and 2030 offshore wind roadmaps, establish 3-4 GW fixed annual diffusion rates with zones, tendering procedures, clarity and transparency
- Long-term clarity and planning encourages and maintains confidence in the industry
- It reduces uncertainty, which stimulates long-term industrial commitments
- Investors are more likely to dedicate resources to projects if there is a long-term perspective
- Since Dutch companies perform very well domestically and abroad, they will likely continue to capture a significant share of the domestic market
- This will continue to support green growth
- It will also help offset job-losses in declining industries, such as oil and gas

2) Create a dedicated disruptive R&D program line with funding

- A dedicated program line stays ‘blind’
- It does not pick winners or play favorites, but it means disruptors do not have to compete with sustaining innovators for the same pot of funding
- It promotes adaptability by increasing product offerings and industrial diversity, which helps prepare for future shocks
- It should NOT replace existing R&D funding programs since these R&D program lines work well and are well funded

3) Establish demonstration zones and/or spots on commercial farms

- Create demonstration zones for all marine renewable energy technologies & disruptive offshore wind
- Alternatively (or in addition), establish mandatory disruptive demonstration spots on new commercial offshore windfarms. For example, require at least two turbine spots to contain disruptive innovations, such as a radical turbine or foundation – can be blind or targeted variety
- Allocate funding to cover the cost difference
- It brings confidence to startups & helps avoid lock-in
- Helps mitigate the high costs of mobilizing expensive vessels, cranes, etc. just for one demonstrator by spreading costs across an entire commercial offshore windfarm
- For floating offshore wind, medium-scale demonstration is still possible in the Netherlands. It may be necessary to facilitate and support international collaboration to secure full-scale demonstration projects in deeper waters

4) Establish installed capacity targets for disruptive innovations

- Following demonstration zones, upscaling is the next step
- Therefore, it is important to help foster a commercial-scale market to reduce costs, improve the technology and further demonstrate the validity of products for use domestically and as an export
- For example, establish installed capacity targets for tidal, wave & blue energy
- This also helps build investor confidence and participation from the private sector

5) Develop strategies and programs to help scale-up disruptive innovation

- Beyond demonstration zones, the entire innovation eco-system should work towards bringing new technologies to the market
- Includes guiding the technological process, legitimizing technologies, establishing networking organizations and allocating funding
- Otherwise, we may not capitalize on our investment
- For example, why invest in wind turbine technology, radical foundations or other maritime technologies without upscaling strategies?
- Importantly, it does NOT replace existing funding mechanisms, networking organizations or support for classic offshore wind

6) Establish an industrial policy task force

- An industrial policy task force can help assess domestic and international industry trends and needs
- It can then help develop an industrial policy targeted towards capturing new markets and technologies
- Balance expertise and relatedness (what we're good at) with what may be needed in the future
- The industrial policy task force can complement the Dutch climate agenda, not replace it
- The export of renewable energy technologies, skills and products contributes to the global energy transition and serves as a valuable export product

6 suggestions in short

1) Convert long-term offshore wind **roadmap** into a concrete 3-4 GW annual diffusion plan

2) Create a dedicated **disruptive R&D program line** → stays 'blind' (does not pick winners), but means disruptors don't have to compete with sustaining innovators for the same pot of funding

3) Establish **demonstration zones** and/or **spots** on commercial farms for disruptive technologies. For floating offshore wind, it may be necessary to support international collaboration to secure full-scale test sites

4) Establish **installed capacity targets** for each of these technologies

5) Develop strategies and programs to **scale-up disruptive innovation**, otherwise we may not capitalize on our investment. Does NOT replace existing programs

6) Establish an **industrial policy task force** to assess international industry trends and create a targeted strategy to capture new markets and technologies. Does NOT replace existing carbon mitigation and reduction mission-oriented policies

Conclusion

- The offshore renewable energy innovation system is **largely resilient** to collapse or failure – strong market capture, industry, knowledge, networking
- However, there is **major lock-in** to a few core industries, such as jack-up vessels & monopile foundations
- Many potential missed opportunities – tidal, wave turbines; floating foundations; alternative fixed-bottom foundations
- Some potentially captured disruptions – motion-compensated installations; blue energy; radical turbines; suction-bucket foundations
- Some potentially captured radical sustaining innovations – slip-joint; quieter monopile hammers; power-to-x
- It is crucial to maintain support for all potentially captured innovations, both incremental, radical and disruptive
- Potential to convert missed opportunities into captured opportunities – knowledge, experience & relatedness are present: directionality and large-scale support are missing

Be a big fish in a big pond

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Appendices

Government supported offshore renewable energy R&D projects

	Sustaining	Disruptive	Totals	Ratio
Discovery	17	4	21	425%
Development	66	19	85	347%
Demo	33	10	43	330%
Total	**116**	**33**	**149**	**367%**

*The numbers represent the number of government funded R&D projects for offshore renewable energy by category and TRL group

+ Sustaining refers to incremental plus radical R&D that improves the current offshore wind design and business model; disruptive is all other R&D (within offshore wind and other offshore RE tech. dev.). It currently performs worse, but has a greater technological and market potential

Breakdown of disruptive offshore renewable energy R&D projects

	Wind turbines	Floating	Kites & airborne systems	Foundations	Floating solar	Tidal turbines	Offshore geothermal	Installations	Towers	Totals
Discovery	1	1	1	0	0	0	0	1	0	**4**
Development	8	1	2	2	0	0	1	5	0	**19**
Demo	3	0	0	2	1	1	0	2	1	**10**
Totals	**12**	**2**	**3**	**4**	**1**	**1**	**1**	**8**	**1**	**33**

Full R&D breakdown by category

R&D Category	Sustaining incremental	Sustaining breakthrough	Disruptive	Totals
Installations	9	4	8	**21**
Foundations	5	0	4	**9**
Technology coupling	5	6	0	**11**
O&M	19	0	0	**19**
Transition piece	0	5	0	**5**
Noise mitigation	3	4	0	**7**
Weather forecasting	8	0	0	**8**
Design and planning	15	0	0	**15**
Energy island	0	2	0	**2**
Vessels	1	0	0	**1**
Towers	3	0	1	**4**
Wind turbines	10	5	12	**27**
Floating	0	0	2	**2**
Cables	4	0	0	**4**
Ecology	4	0	0	**4**
Decommissioning	1	0	0	**1**
Kites & airborne systems	0	0	3	**3**
Floating solar	0	0	1	**1**
Tidal turbines	0	0	1	**1**
Oil and gas end of life	3	0	0	**3**
Offshore geothermal	0	0	1	**1**
Totals	**90**	**26**	**33**	**149**