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The Clean Energy Technology Investment Attractiveness Scan (CETIAS)

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Summary

To realise global climate change mitigation and adaptation ambitions, the world economy must drastically and rapidly reduce its reliance on fossil fuels, and thus transition to cleaner fuel sources. A successful energy transition will require coordinated global action across multiple areas including capacity building, institutional strengthening, and **mobilisation and provision of financial resources.**

Transitioning to clean energy will cost trillions of US$ globally every year, and billions of euros in the Netherlands alone. Current investment levels are insufficient to achieve global and national climate and energy targets, and thus efforts need to be made to overcome the obstacles to scaling up and accelerating investment flows to the energy transition. These obstacles range from unfavourable risk-return profiles for clean energy technology investments, high transaction costs, and a lack consistent information and knowledge about the investment risks and opportunities of investments in clean energy technologies.

This working paper presents ongoing work by TNO to address the obstacle of a lack of information and knowledge about the investment risks and opportunities of investments in clean energy technologies. TNO is developing a tool called the Clean Energy Technology Investment Attractiveness Scan (CETIAS), which provides a structured way of assessing investment attractiveness across different dimensions – policy, economic, social, technological, and environmental.

Section 1 of this paper sets the scene by highlighting the importance and relevance of the topic of sustainable finance, as well as describing the objectives, target audience, scope and approach of the research. Section 2 describes the literature sources and building blocks upon which the CETIAS is based. Section 3 describes the underlying methodology of the CETIAS. Section 4 presents a ‘mock-up’ of the CETIAS product. Section 5 describes some of the challenges and limitations of developing such a product. Finally, section 6 elaborates on further research and development that TNO will be undertaking on the CETIAS.

1 Introduction

1.1 Sustainable Finance

The Paris Agreement sets the goal of keeping global average surface temperature rise this century to ‘well below’ 2 degrees Celsius above pre-industrial levels, and to pursue efforts to limit the rise to 1.5 degrees. To achieve this goal the world’s economy is required to drastically and rapidly reduce its reliance on fossil fuels, and transition to cleaner fuel sources. A successful transition will require coordinated global action across multiple areas including capacity building, institutional strengthening, and **mobilisation and provision of financial resources.**

The energy sector is the largest source of greenhouse gas (GHG) emissions by sector globally, being responsible for around 35% of total anthropogenic GHG emissions. Approximately 90% of energy-related emissions are derived from CO_2 from burning fossil fuels (IPCC, 2014). Transitioning to clean energy will cost trillions of US$ globally every year (IEA, 2017; New Climate Economy, 2016; IFC, 2016; IEA, 2014). Average annual additional investments in the EU alone are projected to amount to €38 billion (US$45 billion) between 2011-2030 to achieve the EU’s climate and energy goals (EC, 2018). In the Netherlands, to meet the targets set out in the Dutch Climate Agreement, cumulative investment of €56-75 billion is required across all sectors between 2019 and 2030, and €32-33 billion in electricity production alone (PBL, 2019). Clearly, as large scale deployment of clean energy technologies will be required to reduce the world’s reliance on fossil fuels, a substantial proportion of mobilised financial resources will need to be spent on the deployment of more technically and commercially mature clean energy technologies (e.g. solar PV, wind onshore and offshore, etc.), as well as those technologies that are considered to be less mature (e.g. hydrogen, geothermal, etc.).

At the European level, the focus on growth in sustainable finance and investment is highlighted by the recently published EU Taxonomy, which is “a tool to help investors, companies, issuers and project promoters navigate the transition to a low-carbon, resilient and resource-efficient economy” (EC, 2020). The Taxonomy sets performance thresholds for economic activities that will improve access to green financing for companies, issuers, and project promoters, and thus help financing the transition to a low-carbon economy. According to the Technical Expert Group (TEG) on Sustainable Finance, the tool is “one of the most significant developments in sustainable finance”, and is likely to have many implications for investors and issuers in the EU and beyond (EC, 2020).

In the Netherlands, sustainable finance is also considered to be an essential part of achieving a successful low-carbon and clean energy transition. As part of the Dutch Climate Agreement, the Financing Task Force provides advice and insight into how the financial market can fund ‘green’ initiatives that can contribute to achieving national climate and energy targets (Klimaatakkoord, 2019). Banks, insurance companies, pension funds, asset managers, and Invest-NL are represented. Invest-NL was officially launched in January 2020 with a share capital of €1.7 billion, and the Ministry of Finance as its main shareholder. It focuses on “financing projects and businesses that drive the energy transition and accelerate the growth of innovative, fast-growing companies” (Invest-NL, 2020). In 2020, the Dutch government launched a green growth fund (*"Wopke-Wiebes-fonds"*) with €20 billion earmarked for investments in three key areas: physical infrastructure, research and development, and education (Ministry of Finance, 2020; de Volkskrant, 2020). These initiatives give a clear signal that the Dutch government is taking sustainable finance seriously.

Given the scale of investment that is required to achieve EU and Dutch climate and energy transition goals, clearly public sector investment alone will be insufficient. Scaling up private sector investment is required (Klimaatakkoord, 2019). Currently, investment levels fall short of the required levels, globally and in the EU (Polzin, 2017; EIB, 2020). Researchers identify multiple causes of this problem, such as unfavourable risk-return profiles compared to alternative investment opportunities, a lack of transparency on climate-related risks by corporates and institutions, unacceptably high transaction costs, and a lack of knowledge on green infrastructure investment risks and opportunities (OECD, 2015; Hafner et al., 2019). Overcoming these obstacles is a priority, for all stakeholders involved in the energy transition, including policymakers and (potential) investors, to increase and accelerate the flow of capital that is needed to finance the transition.

1.2 Research purpose and target audience

TNO is working to address the obstacle of a lack of knowledge on investment risk and opportunities in clean energy technologies. TNO has a unique knowledge position and reputation in the Netherlands as a research organisation with strong know-how and expertise about innovative clean energy technologies, and technologies that are already being deployed, both of which are needed for a successful energy transition. TNO conducts technical, societal, and economic research in the domain of the energy transition, and thus views the transition from a variety of different perspectives, making TNO well-placed to explore investment risks and opportunities that can either hinder or facilitate the transition.

TNO has conducted a set of interviews with institutional investors in the Netherlands, which were designed to learn more about their clean energy investment strategies. During these interviews, TNO observed a demand from investors for better quality information and knowledge about investment risks and opportunities of clean energy technologies. We identified the need for a standardised framework to assess the attractiveness of different clean energy technologies, for institutional and other types of investors. We briefly discussed this idea with the Dutch Ministry of Economic Affairs and Climate (EZK), and agreed that such a framework could also help improve the understanding and knowledge of policymakers about how investors make decisions on clean energy technology investment, and how different policy and regulatory interventions could influence these decisions and help scale up and accelerate capital flows to the sector.

The objective of TNO's research is to improve the understanding of, and information available to, key stakeholders (primarily policymakers and investors) in the Dutch energy transition about the investment attractiveness of different clean energy technologies. To achieve this, TNO is developing the Clean Energy Technology Investment Attractiveness Scan (CETIAS), which provides a structured way of assessing investment attractiveness across different dimensions – policy, economic, social, technological, and environmental. The CETIAS is being developed with two types of stakeholder as the main target audiences: 1) policymakers, to help them better understand how and why private investors in the clean energy transition make investment decisions, and identify policies and regulations that can help to overcome the bottlenecks to scaling up and accelerating private investment; and 2) specific types of investor who seek to improve their understanding of the risks and opportunities, and thus better inform their strategic decision-making, on investments in clean energy technologies. Examples of investors for which the CETIAS could be particularly relevant are Invest-NL and some Dutch commercial banks who have expressed the need for more information and knowledge about clean energy technology investments.

The target audience of the CETIAS is not restricted to the two stakeholder groups mentioned above. Other knowledge institutes, consultants, universities, industry associations, project developers, companies, and other groups are all examples of stakeholders that have an interest in clean energy technology investment. The CETIAS attempts to provide a structured way of looking at investment attractiveness at the technology level, which can be useful for a wide range of stakeholders who are working on the Dutch energy transition. All of these stakeholder groups, to varying degrees and from different perspectives, can benefit from improving their understanding of the investment risks, opportunities, and ultimately attractiveness of clean energy technologies.

1.3 Scope and approach

The methodology underpinning the CETIAS builds upon a well-defined set of criteria that provide a framework for assessing the investment attractiveness of clean energy technologies. The CETIAS is designed to be able to answer the fundamental questions of whether a technology is an attractive investment for a specific investor type or not, and why.

Following exchanges with investors and EZK, TNO conducted a review of relevant literature and other publicly available resources (see Section 2 for an overview), which confirmed that there is a gap in research and methods that are designed to scan clean energy technologies to assess their investment attractiveness. Additional exchanges with Dutch commercial banks and Invest-NL have supported our observation that there is a need for such a framework.

The CETIAS is designed to scan technologies that are considered to be near to the end of the *valley of death*, i.e. technologies that are considered close to being commercially deployed. Companies or project promoters who are deploying these technologies can secure finance from ‘early stage’ investors, such as venture capitalists, as well as other investor types who are active further along the financing cycle. At the post-valley of death stage in their financing cycle, companies or project promoters are starting to make revenue and become more attractive to a wider spectrum of private investor types. The CETIAS is (currently) not designed to scan technologies that are still considered to be in the *valley of death,* which includes technologies that still require research and development funding. Companies or project promoters working with technologies that are at these levels of maturity require accelerator, seed or angel type of investment capital, to fund activities such as building or testing a prototype of the technology (see Figure 1).

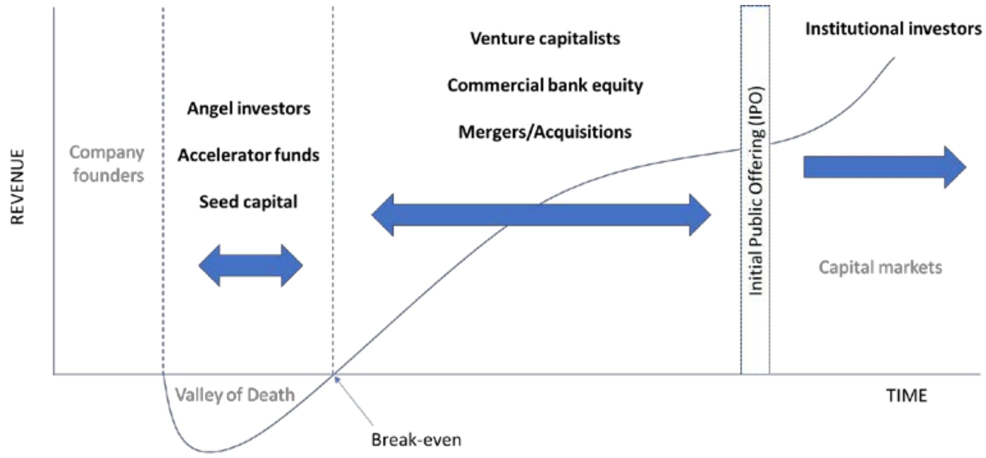

Figure 1: Financing cycle of a company, showing the different types of investors at different stages.

The core of the CETIAS is built upon the well-known PEST (political, economic, social, and technological) framework, which has been adapted for the purpose of the CETIAS to include an Environmental category (see section 2 for further explanation). The CETIAS also builds upon literature on sustainable finance and sources that (attempt to) build methodologies to assess readiness levels (RLs) in different contexts, such as the readiness of a technology to be commercially deployed, or the readiness of society to adopt processes or technologies.

We have conducted a first round of feedback on the approach and content of the CETIAS, by consulting experts internally at TNO. Following this first expert consultation round, we updated the methodology and created an illustrative example of the CETIAS for offshore wind (see section 4). We plan to further develop the methodology, and undertake additional expert consultation rounds, both within TNO and with external stakeholders, including investors, policy makers, and other relevant parties. We will look then validate the CETIAS by applying it to specific clean energy technologies.

This working paper presents the ongoing work of TNO on the development of the CETIAS. The CETIAS is being designed to generate a series scans on the investment attractiveness of clean energy technologies in the Netherlands. The scans will outline the drivers that influence the investment attractiveness of different technologies, based upon a standardised set of criteria and scoring scale that has been verified by TNO and external stakeholders.

Section 2 provides an overview of the literature and resources upon which the CETIAS is based, including the state of the art of different readiness levels, and how they are relevant to, and have informed, the development of the CETIAS.

2 CETIAS: How did we get there?

Literature and other public sources provide important building blocks for the CETIAS (see figure 1). Literature on sustainable energy technology investment identifies the context, relevant themes and criteria for CETIAS (see section 2.1). The CETIAS uses the PESTE framework as a basis for the assessment (see section 2.2). The CETIAS aligns with and builds upon existing efforts that attempt to develop methodologies for comparable or similar purposes. These include various readiness level frameworks, which are described in section 2.3. Conducting a review of available resources about these readiness levels has informed the development of the CETIAS by helping to identify: 1) to what extent the objectives of different readiness level methodologies are aligned with that of the CETIAS; 2) how to include the readiness (or maturity) classification of technologies in the CETIAS; and 3) the different assessment dimensions that should be considered when developing the CETIAS.

2.1 Literature: the investment attractiveness of clean energy technologies

Literature that studies the attractiveness of clean energy technology investment can be divided into two streams: 1) the role of governments and policy makers in supporting this, as part of their climate- and energy transition agendas and commitments; and 2) the investors' perspective on clean energy investment. European member state governments are involved in shaping the energy landscape of the future in various ways. An example of direct involvement of government is the Dutch development plan for offshore wind, including far-reaching de-risking and simplification of tendering of predeveloped areas in the North Sea (Tennet, 2016). Halstead et al. (2019) argue that such governmental involvement in sustainable energy deployment, including design of suitable policy instruments (such as competitive bidding), can drive down the cost of capital by mitigating (perceived) investment risks, and thereby improving the investment attractiveness. Waissbein et al. (2013) and BNEF (2016) both confirm the important role of governments and options available to them for de-risking renewable energy investment with public instruments such as policy and public financing de-risking instruments. Other criteria relating to the role of policymakers and governments, are political stability, policy risk including 'grandfathering', and the role of public finance (BNEF; 2016; DiaCore, 2016; IRENA, 2016).

The second stream of clean energy investment attractiveness literature addresses the investors' perspective on clean energy investments. Investment attractiveness is based upon the risk-return profile of the investment (Merton, 1973). Risk is a main barrier to deployment of renewable energy technology (Kaminker and Stewart, 2012). Egli (2020) shows that risk, as seen by different types of investors, can be decomposed into different elements – policy technology, market, resources, regulation – and that the contribution of these elements to investment risk can change over time. Whereas Egli (2020) focuses on the risk of clean energy technology investments, Ozorhon, Batmaz, & Caglayan (2018) look at both risk and return elements. They explain that when assessing the attractiveness of renewable energy investments, there are more than only financial factors to be considered (see Figure 2). These *external* factors can influence the risk and profitability potential of renewable energy investments.

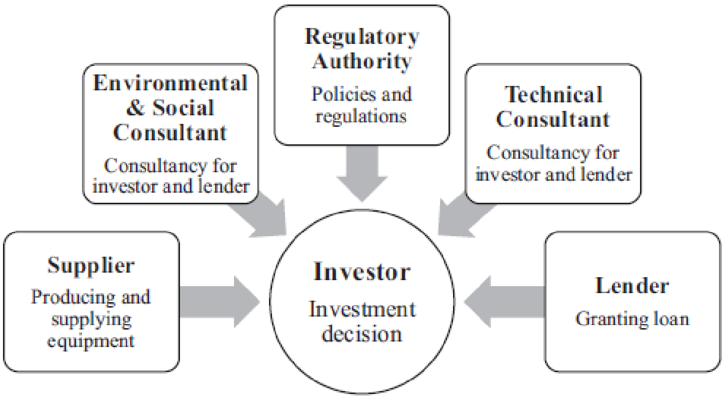

Figure 2: Stakeholders affecting the investment decision (Ozorhon et al., 2018)

2.2 PESTE Framework

The PEST (political, economic, social, and technological) framework provides the basic structure for developing core assessment methodology of the CETIAS. In strategic management literature and practice, and in innovation management practice, the PEST framework (or one of its variants) is frequently used as a scanning tool, to support strategic decision making, for example deciding upon the type of product to launch in a geographical region. Themes and criteria identified in strategic management literature that are relevant to clean energy investment attractiveness, align well with the PEST categorisation. The four PEST categories – political, economic, social and technological – can help to describe specific, external facilitating or hindering factors of the region (Sammut-Bonnici & Galea, 2015). The PEST framework is open to interpretation and there exists flexibility in how it is applied, depending on the innovation, commercial or technological context. This flexibility is a useful characteristic when developing a new methodology, and PEST provides a solid basis from which to build the CETIAS.

In assessing clean energy technology investment attractiveness, environmental factors are also relevant, and should be added to PEST to create a PESTE framework. There is increasing attention to environmental, social and governance (ESG) criteria by investors when assessing investments (observed through interviews with investors and ongoing TNO projects). Environmental aspects are seemingly increasingly relevant for investors during investment decision-making processes (Eccles & Klimenko 2019). In 2006, when the UN Principles of Responsible Investment (UN-PRI) was launched, ESG was primarily approached by investors as a part of corporate social responsibility (CSR). Today, climate change is, especially by larger investment firms, increasingly seen as a system-level risk that they simply cannot ignore. The UN-PRI are signed by over 3000 asset owners, investment managers and service providers in the financial industry. ESG analysis is increasingly integrated into the financial activities of asset managers and or pension funds, such as the Dutch pension fund ABP and asset manager BlackRock (Eccles & Klimenko 2019). This is closely aligned with the overall objectives of the UN-PRI to: 1) understand the investment implications of ESG factors; and 2) support its international network of investor signatories in incorporating these factors into their investment and ownership decisions (UN-PRI, 2019).

2.3 Readiness Levels

A readiness level (RL) helps to assess the level of maturity of one, or usually multiple, aspects of a technology, an application or an organisation (e.g. a start-up company). RLs are developed to create a common understanding across different departments in a company, or different stakeholders in a market, and to communicate progress. Moreover, RLs make it explicit which steps should be taken before a technology or application is ready for full-scale deployment, or the company becomes a good investment case (Mankins, 2002; Blank, 2014). These three aspects - maturity, common understanding, and deployment – align well with the overarching objective of the CETIAS, of developing a standard framework for understanding the attractiveness of an investment in a clean energy technology.

We have identified six RLs from publicly available literature and other sources, including non-publicly available research conducted by TNO. Each of these RLs are (at least partially) relevant for the CETIAS tool. They all contain information and reasoning that can inform the development of criteria that directly impact an investors' decision-making about investments in clean energy technologies. The remainder of this section describes the work that has been done thus far on developing these RLs.

Technology readiness level
NASA developed the technology readiness level (TRL) scale in the 1970s, originally with the aims of enabling standardised technology readiness assessment, effective communication among NASA departments, and coordination of R&D projects (Mankins, 2002). As an inter-organisation categorisation and strategy-helper tool, the TRL was used to enable a technology push strategy, manage risk, provide guidelines to assess technologies by independent parties, and safely hand off and procure technologies (Héder, 2017).

Since its development, the TRL method has been adopted by commercial companies, research institutions and bodies such as European Commission as a standard framework to measure the maturity of technologies in their research programs such as Horizon 2020 (EC, 2017). It has become a well-known scale of technology maturity, which is used outside the context for which it was originally intended (space programs), in different domains (policy, technology, innovation, and finance), and sectors (Héder, 2017). The main purpose of the TRL has gradually evolved to a metric that shows how far a technology is from being ready for use in its intended operational environmental; product readiness to be marketed (Héder, 2017).

Research suggests a significant inverse relationship between technology readiness and perceived risks of the technology (Heslop et al., 2001; Engel et al, 2012): higher levels of technology readiness signal lower perceived technical risk and vice-versa. Subsequently, within the US it is seen as normal that only a small fraction of low TRL projects reach higher TRLs. This technology drop-out rate risk is less acknowledged in the European (research agenda) context, but is an important risk that can be managed (Héder, 2017).

TRLs can be used as a proxy for technical risk and uncertainty in the CETIAS, which are important factors for investors to consider when making investment decisions.

Investment readiness level
Steve Blank developed an Investment Readiness Level in 2013 to assess how investment-ready a start-up company is. It describes standard steps a start-up needs to take to validate its business model: each of its 9 levels show the evidence a start-up can provide to demonstrate that their business model is working, and advice about the next milestone they should be focusing on. This helps investors assess risks and rank start-ups according to their maturity level.

The CETIAS is being designed to assess investment attractiveness of a specific technology, and not companies that develop that technology. This is a key difference from the purpose of Blank's methodology. Nevertheless, the market-related aspects, such as market analyses and profitability, in Blank's method are important for an investor, and thus provide inspiration for development of the CETIAS.

Integration & system readiness level
The TRL is a measure of the maturity of a standalone technology, with a view towards operational use in a system context. The TRL is limited when the assessment is abstracted from an individual technology to a system context, which may involve interplay between multiple technologies (Sauser et al., 2006). The US Department of Defence identified the need to develop a method for assessing the readiness level of a system consisting of several technologies, each with their own TRL. The system readiness level is based on the basic assumptions that: 1) the total system is greater than the sum of the parts, and there are consequences for not understanding the dynamics of each part; and 2) there is causality between parts, subsystems, systems, and the environment they function in. The system readiness level is a function of individual TRLs of technologies in a system, and the maturities of the links between them, which is defined based on a scale of integration readiness levels (IRLs) (Sauser et al., 2006).

The system perspective is relevant for assessing the investment attractiveness of a clean energy technology in the context of the (required) energy system, its supporting infrastructure, and the value chain it relies on to operate. For example, electrolysers used to produce green hydrogen require, among other things, availability of affordable and sustainable power, hydrogen transport infrastructure, as well as downstream assets that will use the hydrogen that is produced, for example fuel cell cars or hydrogen boilers.

Innovation readiness levels
We have identified two different innovation readiness levels based on previous research at TNO (TNO, 2019a):
1. *KIC InnoEnergy[1] innovation readiness level (REEEM, 2017) :* Assesses the level of maturity of an innovation project, in particular emerging businesses (i.e. a start-up or venture). The tool is qualitative, helping to analyse an innovative technology or product, at a project level. The tool helps to analyse the dynamics of innovative processes within a project by considering all the dimensions that are crucial for the success of a new product or service.
2. *Innovation readiness level (Tao, et al., 2010):* Helps to monitor and control improvements of an innovation based on a framework which illustrates the development of an innovation during the life cycle of the technology (Tao, et al., 2010).

[1] KIC: Knowledge Information Centre InnoEnergy. Now called EIT InnoEnergy.

Both innovation readiness levels focus on the entire life cycle of a technology or project, starting at TRL 1. The CETIAS focuses on assessing the attractiveness of investment in clean energy technologies classified as around TRL 7 or higher. Thus, both of these innovation readiness levels are broader and more generic, than the scope of the CETIAS. The product life cycle approach combined with the approach of the model of Tao, including a wide range of dimensions such as technology, market, consumer, societal and organisational aspects is an interesting one. The integrated and systemic approach of both innovation readiness levels covers multiple dimensions (compared to most other readiness levels that focus on one specific dimension), which provides a different perspective that can inform the development of the CETIAS.

Regulatory & Market Readiness Level
Kobos et al. (2018) show the importance of the link between the TRL method (*can we build it?),* regulatory readiness level (RRL) (*can we accept it?*) and market readiness level (MRL) (*will they adopt it?*). The core factors underlying the RRL cover the technology's access to the regulatory process, security of regulatory support (e.g. political capital built through influence, relationships, trust and goodwill), and the effectiveness of that regulatory support to deliver meaningful legislation to support the technology (e.g. reducing legal barriers). Finally, environmental constraints are considered before the final stage of political (and social) acceptability is assessed (Kobos et al., 2018). It embraces the idea that regulation can stimulate development and deployment of the technology, and vice versa. The MRL method includes assessing the access to the market base, the security of financial capital, manufacturability and consumer utility. Kobos et al. (2018) state that the MRL assessment follows the TRL and RRL.

Regulatory and market aspects are crucial for an investor when considering investments in clean energy technologies. The RRL includes various regulatory aspects (e.g. policy (un)certainty and political (and social) acceptability) that inform the development of the CETIAS. The MRL covers the basic market considerations and requirements for technology deployment, and mentions the security of financial capital, which is considered when developing the CETIAS.

Societal embeddedness level
The Societal Embeddedness Level (SEL) is a method to assess how socially embedded a technological innovation in a specific sector is. The method complements the TRL method by supporting technology developers in understanding the current societal embeddedness of a technology, and the actions that should be taken to ensure the technological innovation is embedded in society (TNO, 2019a). The method has a broad scope as it includes non-technical aspects, such as environmental, stakeholder, market, policy, legal, political, and financial in the assessment method. It also includes access to financial resources as a component: "*the extent to which the developers have access to the financial resources to implement the innovation in society. This means that the required actions to embed an innovation in society have to be financially supported, i.e. costs and benefits, (long-term) financial commitment*" (TNO, 2019a). The CETIAS is designed to further explore this dimension for different clean energy technologies.

2.4 Building blocks

The sections on clean energy investment attractiveness, the PESTE framework, and readiness levels provide background and input for the CETIAS development. This section describes how these components combine to form the building blocks of the CETIAS.

Use of readiness levels

RLs do not (explicitly) address investment attractiveness. They include factors that can be used to assess technological, innovation, integration and system, regulatory and market, or societal readiness of a technology, application or organisation. The various RLs provide inspiration for themes, criteria and indicators of the CETIAS framework. The scope and focus of each RL, and the elements that are relevant for the development of the CETIAS, are summarised in Table 1 below. For example, the TRL itself can be used as a proxy for the technological risk an investor faces when investing in a specific clean energy technology. What is common for all RLs is the idea of assessing each criterion on a spectrum, for example, from “not supported” to “fully supported”. Investment attractiveness could potentially be assessed in a similar way to technology readiness: by defining levels of maturity for each of the investment attractiveness criteria. Similarly to the RLs, the CETIAS is being designed to create a comparable and consistent assessment across different criteria.

Table 1: Overview of readiness levels, their scope, and the elements that are useful for the CETIAS.

Readiness Assessment	Focus of method	Usefulness for CETIAS
Technology Readiness Level (Mankins, 2002)	The technical and commercial maturity of a technology	Technical risk and uncertainties
Investment Readiness Level (Blank, 2014)	Investment readiness of start-ups / stage of business model validation	Market factors and level of uncertainty
Integration & System Readiness Level (NASA - Sauser et al., 2006)	Combining TRL with integration into the existing system	Successful technology deployment depends on compatibility with existing infrastructure
Innovation Readiness Level (KICInnoEnergy - REEM, 2017, Tao et al., 2010)	Multi-dimensional assessment of the stage of a product, service or project during its life cycle	Integrated / multi-dimension approach, technology and organisational risk
Regulatory & Market Readiness Level (Kobos et al., 2018)	Combining TRL with the challenges of receiving regulatory permission to enter the deployment phase and to achieve a substantial market share	Market and regulatory risks, levels of political support

Readiness Assessment	Focus of method	Usefulness for CETIAS
Societal Embeddedness Level (TNO, 2019a)	Embedding of an innovation in (a part of) society, as an addition to the TRL	Multi-dimensional approach, importance of societal acceptance and financial resourcing

It is important to note that not all RLs presented here are fully described in literature or other publicly available sources. Several are still under development, and thus parts of the methodologies are not fully elaborated, such as definitions of the criteria or the assessment processes and structures. Additionally, many of them are only theoretical frameworks, and have yet to be validated through practical application. This does not mean that elements of these RLs are not useful for the development of the CETIAS, and indeed some of the CETIAS criteria are heavily based on criteria from these RLs.

Use of clean energy investment attractiveness literature

Clean energy investment attractiveness literature provides valuable input to the development of CETIAS themes, and the further specifying of criteria and indicators. Based on Ozorhon et al. and a review of other relevant resources, we identified five main categories of stakeholders that can either facilitate or hinder renewable energy investment (see Table 2). These categories show that there are environmental and social, technical and economic (including regulatory), reasons that motivate stakeholders that influence an investor's decision-making. The work of Ozorhon focuses mostly on the micro-economic level and corporate or business decisions regarding investments in renewable energy. Given our objective of assessing the attractiveness of a specific clean energy technology in a macro environment, we have taken a more strategic and overarching perspective of the investment attractiveness of a technology. Hence, Ozorhon's criteria are only useful when we can transform them to a macro-context. We do this through use of the PESTE framework.

Use of PESTE

Literature on clean energy investment attractiveness aligns with the PESTE categories. Applying a slightly modified PESTE framework (see Table 2 which shows the CETIAS themes) provides a basis for categorising, capturing, and defining the relevant themes to assess the investment attractiveness of clean energy technologies. We aim to actualise the PESTE themes by developing a set of clean energy technology investment attractiveness criteria that are as close to mutually exclusive and collectively exhaustive as possible (see section 3*).*

Conclusion

Observations from studying the different RLs, the PEST framework, and Ozorhon's stakeholder mapping, have highlighted similar themes that could be included in an investment attractiveness assessment. In distilling the common themes from literature and other sources, we have identified the following five themes as the main building blocks of the CETIAS methodology:

1. **P**olicy & Political attractiveness
2. **E**conomic & Financial attractiveness
3. **S**ocial attractiveness
4. **T**echnology attractiveness
5. **E**nvironmental attractiveness

Table 2: Investment attractiveness themes of the CETIAS (adapted from various sources).

	PESTE	Ozorhon	Readiness Levels	CETIAS
Focus	External and macro factors for deciding on (innovation) strategy	Factors affecting RE investment decision making	How to mature technology, application or organization	Investment Attractiveness of Clean Energy Technology
Relevant themes	Political Economic Social Technology Environmental	Regulatory Economic Environmental & Social Technology	Policy & Regulations Market maturity Societal Acceptance System integration Technological maturity Innovation	Policy & Politics Economic & Financial Societal Technology Environmental

3 CETIAS: The methodology

This section describes the underlying methodology of the CETIAS. The central part of the scan is 5 investment attractiveness themes, each containing a set of criteria against which a clean energy technology can be evaluated to assess its investment attractiveness. The methodology is designed with the objective of devising criteria to assess investment attractiveness of clean energy technologies that are mutually exclusive and collectively exhaustive (MECE)[2]. Figure 3 shows the main components of the CETIAS.

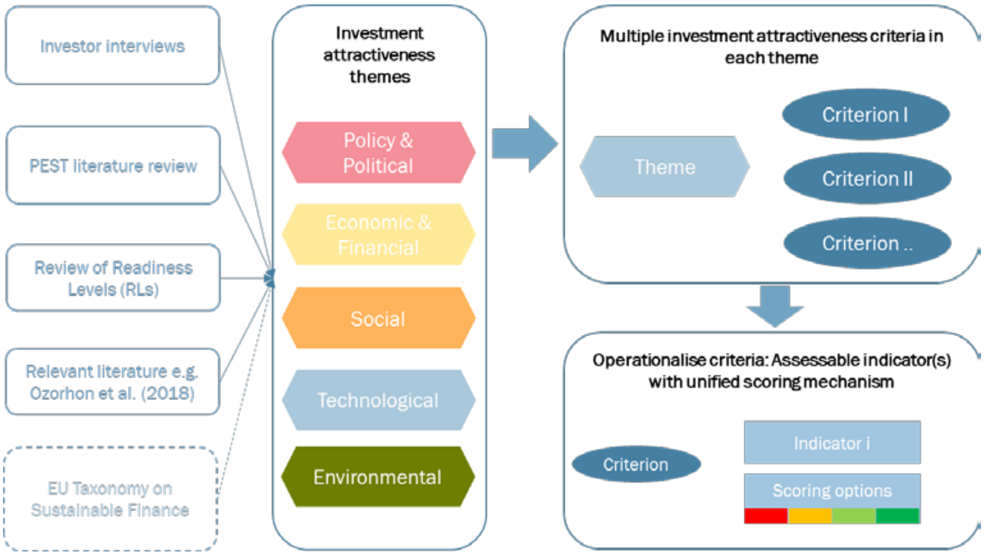

Figure 3: Overview of the main components of the CETIAS.

3.1 From CETIAS themes to attractiveness criteria

Under the 5 themes (PESTE) we develop investment attractiveness criteria i.e. the external factors that can increase or decrease investment attractiveness of a clean energy technology. Each of the following subsections zooms in one of the five CETIAS PESTE themes. Each of the criteria shown here have been included because, either directly or indirectly and either perceived or actual, they influence the risk-return profile of an investment in a clean energy technology. The criteria included in the paper of Ozorhon et al. (2018) are used as a starting point (see Table 3 for the complete list of Ozorhon's criteria). We transform them from a micro-level to a macro-level, and add other investment attractiveness criteria identified from desk research and TNO's own project experience.

[2] The MECE principle is a grouping principle developed at McKinsey & Company that ensures items are separated into subsets that cannot occur at the same time (mutually exclusive), and collectively cover all events.

Table 3: List of criteria from Ozorhon et al (2018).

Technical	Economic	Environmental & Social
Efficiency Reliability of technology Production capacity of the plant Implementation and operational risk Local technical know-how Annual exploitability	Investment cost O & M cost Realization time Financial indicators Service life Risk attitude of the investors Confidence in market Macro-economic environment Availability of funds Policies and regulations	Emission rates Land use Noise Effects on natural environment Social acceptability Job creation Safety

***Disclaimer:** The next subsections present the **draft** investment attractiveness criteria for each PESTE theme. The criteria list and their descriptions are **not final**. They will be further developed and refined in future research.*

3.1.1 Policy & Political

For investment attractiveness, the theme Policy and Political refers to the risks associated with the stability and durability of a political regime, including political events that can impact the value of investments. Policy (and regulatory) risk is a subset of political risks (BNEF 2016) and deals with existence and design of support mechanisms and risk mitigation policies. In this theme, we also include national debates that can precede policy making, for example the several sectoral climate round tables that resulted in the Dutch *Klimaatakkoord*, 2019.

The policy and political angles are not extensively addressed by Ozorhon's criteria, although they mention (the lack of) regulation and administrative burden as attractiveness criteria. BNEF (2016) state that policy, politics and regulation can have both positive and negative impact on the "*viability or attractiveness of an investment*" in renewable energy. There are risks associated with the stability and durability of a political regime, including political events that negatively impact the value of investments (IRENA, 2016). BNEF (2016), DiaCore (2016) IEA-RETD (2008) all point out the impact of policy design, and especially the impact and risks of (unexpected and sudden) policy or governmental changes, on renewable energy investments.

Table 4: CETIAS draft Policy and Politics criteria, descriptions, and sources.

Criteria Name	Criteria Description	Sources
National Government Ambition	Alignment of the technology with national government ambition: targets, strategies, and planning on energy and climate.	IRENA (2016)
Policy Design, Instruments and Uncertainty	Existence and design of support policy mechanisms and risk mitigation policies, and the stability and durability of (support) policies.	BNEF (2016); Diacore (2016);

Criteria Name	Criteria Description	Sources
		IEA-RETD (2008)
Market Design, Regulation and Legislation	The governmental strategy and regulation regarding the market of the technology.	MRL; BNEF (2016);
Regulation & Legal: Administration & Permits	The capacity, transparency, efficiency and predictability of governmental bureaucracy and administration in dealing with e.g. licensing, permits	Ozorhon et al. (2018); BNEF (2016)

3.1.2 *Economic & Financial*

Economic aspects are the foundations of an investment (Ozorhon et al., 2018). All investors develop a project to make a return on investment, hence this theme describes the criteria that influence the business case of a typical application of the technology being considered. The financial attractiveness refers to factors, additional to economic factors, that for an external investor improve the financial viability of the investment (so-called hygiene factors), such as the ability of companies to obtain financing. These financial factors do not necessarily influence the profitability of the technology and the application itself.

Both Blank (2014) and Ozorhon et al. (2018) – and in fact many others – express the importance of profitability, usually expressed in common financial indicators such as return on investment, internal rate of return or net present value. Investors do not only look at profitability, but also when they can expect their investment to be profitable: the payback time (cf. Salm, Hille & Wustenhagen, 2016). Profitability and payback time can be estimated, but they differ across technology types, and the company or project that is deploying the technology. Therefore, we include the relative size and uncertainty of operations and maintenance costs (Ozorhon et al., 2018) and market uncertainty for uptake of technology (Blank, 2014 and Kobos et al., 2018).

In clean energy technology start-ups, a lack of collateral or credit history can hinder an organisation when trying to secure a loan or apply for a grant (Bergset & Fichter, 2015 and Kerr & Nanda, 2009). We deduce from this that the ability of a company to obtain financing for deployment of a clean energy technology is one factor which determines the investment attractiveness of that technology.

Ozorhon et al. (2018) mention the investment size as a relevant criterion. Also Mazzucato & Semieniuk (2018) mention that ticket size (investment size) is very important. They stress that the size itself is not a criterion, but that it is the (relative) match between the investment size and an investor's preference that counts. Next to ticket size, we have added two other criteria to this theme based on TNO experience: strategic opportunity[3] and exit strategies.

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[3] This has been discussed within the VoltaChem Innovation Program (www.Voltachem.nl). For example, the development of CO_2 to ethanol technology might not have a positive business case on its own, but can open up markets for higher value chemicals such as antibiotics.

Table 5: CETIAS draft Economic & Financial criteria, descriptions, and sources.

Criteria Name	Criteria Description	Source
Profitability	Monetary value capture for investor	Ozorhon et al. (2018); Blank (2014)
Payback period	The time frame in which the investor can expect its return on investment.	Ozorhon et al. (2018), Salm et al. (2016)
Operation & Maintenance	The relative size and possible range of future operation and maintenance cost.	Ozorhon et al. (2018); Blank (2014)
Market uncertainty	The extent to whether there is a track record or indications of an existing and sizeable market now or in the near future.	Blank (2014); MRL
Investment size (ticket size)	Whether the for the group of interested investors, the ticket size fits within their investment strategy. Not too high and not too low	Mazzucato & Semieniuk (2018)
Strategic opportunity	Strategic importance of technology, e.g. size of other potential markets it can open if the demonstration project is successful	TNO experience
Ability to obtain financing	Whether a typical company or project organisation deploying the technology is able to attract other sources of capital, e.g. loans or subsidies.	Bergset & Fichter (2015); Kerr & Nanda (2009)
Investor Risk Appetite	Investors perceive the risk of investing in this technology as acceptable.	Ozorhon et al. (2018)
Exit strategy	There is a robust business plan with forecasted profitability high enough to ensure required return. The technology can be used to enter new markets and is not only suitable for niche applications. In the country and sector there are developed secondary debt/equity markets for comparable investments.	TNO experience

3.1.3 *Social*

The social theme focuses on the forces within society that can impact the attractiveness of an investment i.e. society's attitudes, opinions and interest, and the way in which they are formed or influenced. Investors, public authorities and lenders have started to place much more importance on social issues (Ozorhon et al., 2018).

Increasingly, investors are looking for international environmental and social standards or guidelines to help assess the companies and projects that they invest in. The United Nations Principles of Responsible Investment (UN-PRI, see section 2.2) is an established example of an attempt to set guidelines for financial institutions on investing responsibly. The UN-PRI provides 6 principles, including supporting tools, that set a global standard for responsible investment. The UN-PRI website contains descriptions of ESG-issues at a global level that investors should be incorporating in their investment decision-making. We have adapted and selected the criteria that are relevant for the current geographical scope of the CETIAS: the Netherlands.

Ozorhon et al. (2018) observed social aspects that can influence renewable energy investment decision behaviour: societal acceptance, job creation and safety. Wang et al. (2009) mention several societal criteria that are frequently used in decision making on sustainable energy investment: Societal acceptability is mentioned as ‘extremely important’; both net and gross job creation in technology lifetime; and other social impacts (in general) can be included. The UN-PRI address similar social criteria (the S in ESG) that should be included in the investment decision process.

Table 6: CETIAS draft Social criteria, descriptions, and sources.

Criteria Name	Criteria Description	Source
Societal Acceptance	The degree to which society or local community accepts deployment of this technology.	Ozorhon et al. (2018); Wang et al. (2009); SEL
Job Impact	Net Direct and indirect job creation during technology life cycle.	Ozorhon et al. (2018); Wang et al. (2009)
Social Impact	The effect of technology deployment on occupational and societal health and safety issues.	UN-PRI; Wang et al. (2009)

3.1.4 Technological

Technological attractiveness refers to the performance and surrounding requirements of the technology that directly affect the economic outcomes (loosely based upon Ozorhon et al, 2018).

Revenue is directly dependent on production, hence proven reliability and technology maturity are one of most important factors in determining project cash flows (Ozorhon et al., 2018). Construction risk (sometimes referred to as implementation risk) and operational risk can directly influence revenue streams (Ozorhon et al., 2018). Improved technical knowledge and skills of the local/regional actors can help to reduce technical problems and decrease repair times.

We have added two additional criteria. Technical excellence (cf. Stein, 2013 and Sengul et al., 2015) is a generalisation of Ozorhon’s criterion ‘energy efficiency’. Critical infrastructure is derived from integration & system RL (Sauser et al., 2006) and TNO experience on system integration and infrastructure (e.g. TNO, 2019b).

Table 7: CETIAS draft Technological criteria, descriptions, and sources.

Criteria Name	Criteria Description	Source
Technology Maturity	The level of technical and proven reliability of the technology.	TRL; Ozorhon et al. (2018; Wimler et al. (2015); Cavallaro & Ciraolo (2005)
Construction risk	The technical risk during construction phase.	Ozorhon et al. (2018)
Operational risk	The technical risk during operation phase.	Ozorhon et al. (2018)
Technical know-how	Technical expertise and know-how of local actors both in construction and operational phases.	Ozorhon et al. (2018); Wimler et al. (2015)
Technical Excellence	The future outlook (potential) for the technology to perform and its potential for the technology to have a competitive advantage over other technologies.	Ozorhon et al. (2018); Stein (2013); Sengul et al. (2015)
Critical Infrastructure	Necessary infrastructure in place for deployment and operation of the technology (application)	Integration & system RL; TNO experience

3.1.5 Environmental

Environmental investment attractiveness of a technology refers to effects or characteristics that are proven to positively impact climate mitigation and adaptation potential of an economy, or in words of the EU taxonomy (EC, 2020) 'to what extent an investment can be considered sustainable finance'. It also refers to the level of slow or catastrophic environmental effects of the technology and the associated economic, administrative or reputational consequences (Financial Glossary, 2011).

Clean energy technologies are shown in the Taxonomy as making a 'substantial contribution' to climate change mitigation (EC, 2020). Therefore, we include EU taxonomy status as a separate criterion. The environmental attractiveness criteria are strongly based on the E-issues in the UN principles of responsible investment (see subsection 3.1.3). Not addressing or taking into account potential environmental factors can have a negative impact on future revenue streams and cause reputational damage to the investor, as well as the technology itself.

Table 8: CETIAS draft Environmental criteria, descriptions, and sources.

Criteria Name	Criteria Description	Source
EU taxonomy status	The status of the technology in the EU taxonomy of sustainable finance.	EC (2020)
Water use	The water use and withdrawal during construction and operational life time.	UN-PRI
Material use	The use of critical materials during construction and operational life time.	UN-PRI
Land Use	The number of conflicting land claims that arise now and in the future.	Ozorhon et al. (2018); UN-PRI
Environmental Incidents	The change in environmental incidents during construction and operational life time	UN-PRI, Wang et al. (2009)

In the next subsection we explain how these criteria are operationalised into a scoring system based on measurable indicators.

3.2 Indicators and the scoring system

The CETIAS currently comprises of 27 clean energy technology investment attractiveness criteria. Each of the criteria is assigned one, but in some cases multiple *indicators.* These indicators are linked to carefully crafted *questions*. The indicator scores (depending on the answers to the questions) are choices on a one-dimensional scale. The answer is specific, but the indicator is not necessarily measurable or observable. Expert judgement needs to be made to score the criteria, preferably with supporting evidence.

The answers are graded on a scale which runs negative to positive. The more positive the answers across the questions, the better this criterion contributes to investment attractiveness. The answer options have four generic options: very negative, slightly negative, slightly positive, very positive. However, for each of the indicators these answers are tailored to the specific criterion. This results in a unified way of scoring the criteria and, as shown in the product description in the next section, means that the scores for a specific clean energy technology can be neatly presented. We provide five examples, one from each of the CETIAS PESTE themes, here to give some insight into the content of the methodology.

Disclaimer: *The development of the CETIAS, in particular the indicators and questions, is still work in progress. The five examples underneath are to be updated in further research.*

Theme: Policy and Political Attractiveness

Criterion: National government ambition – targets, strategies and plans

Indicator: Alignment of the technology with national government ambition

Question: To what extent is the technology included in the national government strategies and plans regarding clean energy transition?

Score	Description
No alignment	There is no specific mention of the technology in strategies and plans. Or the technology is explicitly not preferred
Weak alignment	Technology is not excluded, but not an obvious fit with the vision or strategic ambitions.
Some alignment	Technology is mentioned as part of a successful energy transition and supported by the government
Strong alignment	The technology is considered crucial for a successful energy transition. There are explicit targets budget allocations, and/or legislation in place.

Example – Economic and Financial Attractiveness

Criterion: Operation and maintenance (O&M) costs
Indicator: Projectability of operation and maintenance costs
Question: To what extent are data or models available for projecting future operation and maintenance costs?

Score	Description
No projectability of data	No O&M cost data from comparable assets available (all of the asset's components / processes are novel), only data from theoretical models available
Limited projectability	There is limited data on O&M costs of the main components: for a majority of the O&M costs the data available relates to different operating conditions and / or scale
Partial projectability	There is relevant data on O&M costs for the components that determine at least half of the O&M costs
Full projectability of data	The O&M costs for this type and scale of asset are well-known from previous projects, i.e. at least 90% of the O&M costs can be projected based on relevant data.

Example – Social Attractiveness

Criterion: Social acceptance of technology
Indicator: Sentiment of society towards technology
Question: What is society's sentiment towards the Technology

Score	Description
Very negative sentiment	There is negative sentiment towards the technology, which is expressed through public opposition events (locally or in other countries)
Negative sentiment	There is no public opposition, but regional survey outcomes show slightly negative sentiment towards the technology
Positive sentiment	There is no public opposition and regional survey outcomes show neutral or slightly positive sentiment towards the technology
Very positive sentiment	There is positive sentiment towards the technology and society shows supporting behaviour

<u>Example – Technology Attractiveness</u>

Criterion: Critical infrastructure
Indicator: Availability of critical infrastructure
Question: To what extent is the infrastructure in place for the technology to be deployed

Score	Description (illustrative)
Not available	There is no critical infrastructure that supports deployment of the technology
Partially available	There is some critical infrastructure in place that supports low deployment of the technology
Mostly available	There is critical infrastructure in place that supports medium scale deployment
Fully available	There is a robust critical infrastructure in place that supports large scale deployment of the technology

<u>Example – Environmental Attractiveness</u>

Criterion: Material use
Indicator: Critical Material intensity
Question: What is the relative critical material intensity of this technology?

Score	Description (illustrative)
High material intensity	The technology uses relatively high amount of critical materials.
Medium material intensity	The technology uses an average amount of critical materials.
Low material intensity	The technology production and operation uses a minimum amount of critical materials.
Zero material intensity	The technology production and operation uses no critical materials

3.3 Conclusion

In this section we presented the CETIAS methodology: the 27 criteria and their indicators that are the basis of performing an investment attractiveness scan. The criteria formulation and their indicators are not final. We have presented examples of possible indicators and how to score some criteria based upon the answers to specific questions. In future research, we will develop a guidebook that describes all criteria, indicators and the scoring system for each criterion. This guidebook will also explain how the user of the CETIAS should perform an investment attractiveness scan for a specific clean energy technology. A mock-up of a scan for offshore wind is shown in section 4 for illustrative purposes.

4 CETIAS: The Product

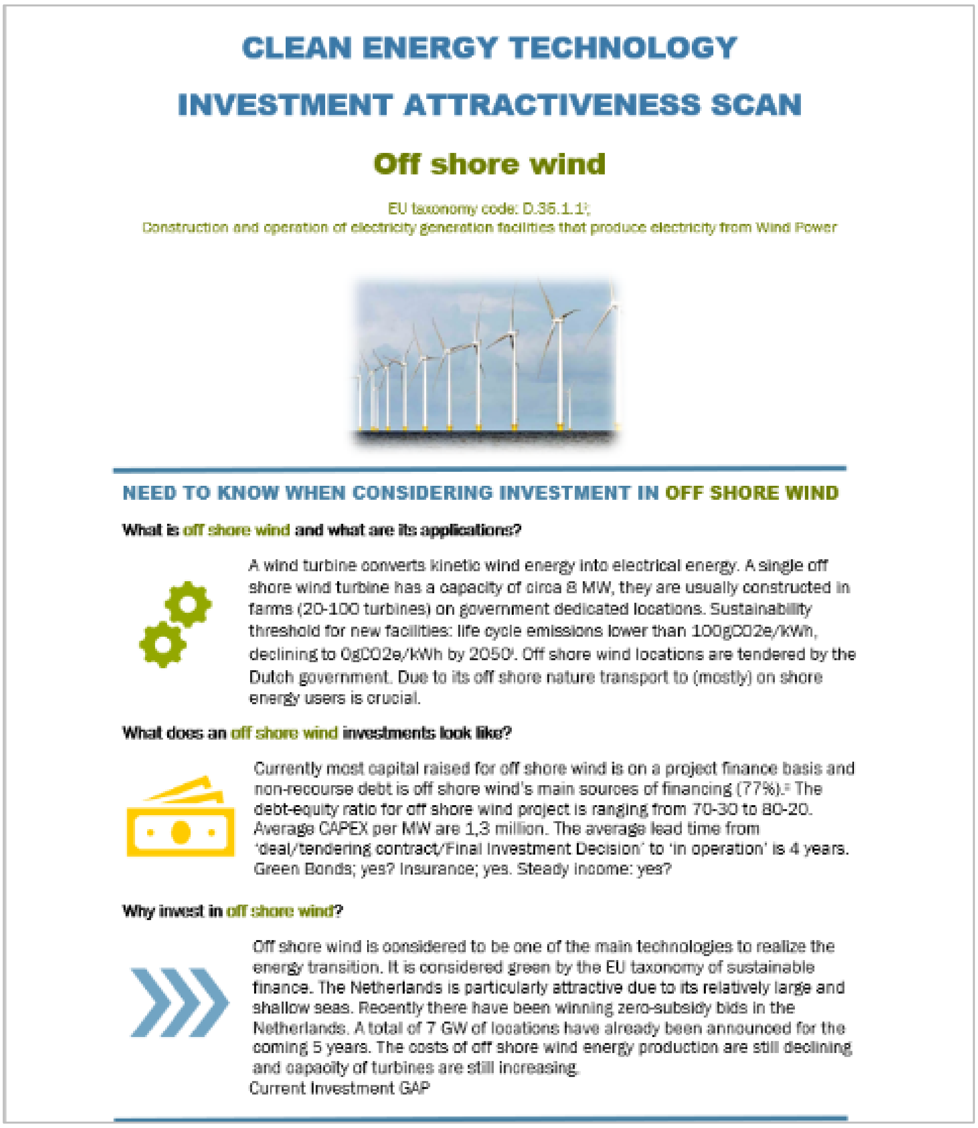
The PESTE analysis in the CETIAS, which we presented in section 3, is the core component of the CETIAS final product. The scan is designed to be applied to clean energy technologies that are near the end of the *valley of death,* from TRL 7 and above, and for the investor types active at these stages. Simply taking a technology, scoring the criteria and then only presenting the results, is not sufficient for the purposes and the target group we want to reach: policy makers and investor types that are active in the scaling-up and deployment of clean energy technologies.

Performing an investment attractiveness scan using the CETIAS methodology requires involvement of stakeholders in the target audience (investors, financial institutions, policy and technology experts). The results of the scan are presented in a short semi-standardised report (approximately 4 pages), which describes the investment attractiveness of the clean energy technology. For illustrative purposes we show in this section how the final scan would look like when undertaken for a clean energy technology. The images shown here are based on a ‘mock-up’ that is made for *electricity generation through wind offshore*.

The CETIAS product contains the following sections:

Page 1: Focus and Pitch
This section provides information that answers the following questions:
- What is the technology?
- What are the characteristics of a typical investment in this technology?
- Why should you consider investing in this technology?

The information will be presented on the front page of the semi-standard report. It will provide a short, concise factual overview of the technology (see Figure 4).



CLEAN ENERGY TECHNOLOGY

INVESTMENT ATTRACTIVENESS SCAN

Off shore wind

EU taxonomy code: D.35.1.1[1];
Construction and operation of electricity generation facilities that produce electricity from Wind Power

NEED TO KNOW WHEN CONSIDERING INVESTMENT IN OFF SHORE WIND

What is off shore wind and what are its applications?

A wind turbine converts kinetic wind energy into electrical energy. A single off shore wind turbine has a capacity of circa 8 MW, they are usually constructed in farms (20-100 turbines) on government dedicated locations. Sustainability threshold for new facilities: life cycle emissions lower than 100gCO2e/kWh, declining to 0gCO2e/kWh by 2050[1]. Off shore wind locations are tendered by the Dutch government. Due to its off shore nature transport to (mostly) on shore energy users is crucial.

What does an off shore wind investments look like?

Currently most capital raised for off shore wind is on a project finance basis and non-recourse debt is off shore wind's main sources of financing (77%).[2] The debt-equity ratio for off shore wind project is ranging from 70-30 to 80-20. Average CAPEX per MW are 1,3 million. The average lead time from 'deal/tendering contract/Final Investment Decision' to 'in operation' is 4 years. Green Bonds; yes? Insurance; yes. Steady income: yes?

Why invest in off shore wind?

Off shore wind is considered to be one of the main technologies to realize the energy transition. It is considered green by the EU taxonomy of sustainable finance. The Netherlands is particularly attractive due to its relatively large and shallow seas. Recently there have been winning zero-subsidy bids in the Netherlands. A total of 7 GW of locations have already been announced for the coming 5 years. The costs of off shore wind energy production are still declining and capacity of turbines are still increasing.
Current Investment GAP

Figure 4: Illustration of CETIAS semi-standard report for Offshore Wind in the Netherlands (page 1)

Pages 2-3: Investment attractiveness scan results

The results of the scan are summarised in a chart that shows the positive and negative highlights of the investment attractiveness of the technology. An overview of the scores for each criterion is displayed using a simple colour coding approach (see Figure 5).

Figure 5: Illustration of CETIAS semi-standard report on Offshore Wind in the Netherlands (pages 2 and 3).

Page 4: Outlook

This section of the scan presents information on potential developments over the next 5-10 years that can impact the overall investment attractiveness of the clean energy technology. For example: are breakthrough cost reductions envisioned or already happening? Has the government announced that the technology will be receive financial support or other public stimulus measures? Is the technology widely acknowledged as a key enabling technology for the energy transition, or the development of the national cleantech industry?

References & further information

The final product concluded with a short section presenting some of the main literature sources used in the assessment, the authors of the scan, experts/institutes that have contributed, and a short description on the CETIAS product and approach (see Figure 6).

OUTLOOK

Refinancing opportunities?

Merchant opportunities?

Decomissioning?

Connected sectors?

Standardization?

Still innovation in off shore wind sector. Technical, grid connections.

Some References

[i] EU technical expert group on Sustainable Finance (2019) Taxonomy Technical Report. Version June 2019
[ii] Wind Europe (2019) *Financing and Investment Trends of the European Wind Industry*. Published online on www.windeurope.org
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Authors			
Contributors			
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ABOUT TNO CETIAS

The Clean Energy Technology Investment Attractiveness Scan has been developed by TNO with the purpose of overcoming .

Some general text in box about development, funds and typical process and purpose.

Some specific for this technology

Figure 6: Illustration of CETIAS semi-standard report on Offshore Wind in the Netherlands (page 4)

A methodology guidebook with clear definitions on themes, criteria and indicators (see section 3), including guidelines and background information on how to use the CETIAS, is being developed. This will complement the semi-standard report.

5 Challenges and limitations

We have observed the following challenges and limitations to the approach and development of the CETIAS framework:

Application scope
The CETIAS is designed to assess investment attractiveness at technology level. It does not assess attractiveness of individual projects applying the same technology. Assessing investment attractiveness at an individual project level can include other factors and context which may result in different criteria that are not directly reflected in the CETIAS. Involving an expert who is experienced in implementing projects with the technology being assessed will help to address this challenge.

Geographical scope
It is challenging to develop a general assessment framework that is applied across different geographical scales (world region, national, subnational). The CETIAS is designed to support strategic level decision-making and policymaking within a specific jurisdiction or national government, while acknowledging that the geographical scope of the energy transition, clean energy technology deployment, and the activities of investors, are all cross border.

A static assessment
The energy transition, as with any transition, is not static. State-of-the art clean energy technologies, market uptake and policy and regulation are evolving rapidly. A technology assessment as proposed in this paper is by definition somewhat static, and any scan would need to be updated on a regular basis.

Overlap and interaction across themes and criteria
In the development of the CETIAS we aim to devise a set of mutually exclusive and collectively exhaustive themes and criteria that impact the investment attractiveness of clean energy technologies. Clear definitions of themes and criteria are essential for the framing and understanding of these. It is challenging to prevent overlap between themes and criteria, given that the CETIAS framework cuts across different domains (policy, technology, innovation, and finance), and different technology applications in a variety of sectors (energy, built environment, industry). One example of this overlap is the support of, or opposition to, clean energy technologies by advocacy coalitions, which overlaps with the societal acceptance of these technologies such as environmental impact (e.g. discussions in the Netherlands around the deployment of biomass or nuclear energy). Clear definitions and guidelines on how to interpret each criterion in the CETIAS is important. The methodology guide that is being developed will include specific definitions and guidance on how to interpret criteria that may overlap.

Development of the CETIAS framework is ongoing. Further verification is required to strengthen the structure and content of the CETIAS, and a process of validation by piloting the CETIAS with specific clean energy technologies. All of these ongoing activities are likely to bring further challenges and limitations. Section 6 presents this future research, which is planned to take place in 2021.

6 Further research & development

Further research on, and development of, the CETIAS presented in this paper is planned. We have identified the following activities which will take place in the coming year(s).

Methodology further development and refining
The methodology that underpins the current CETIAS framework needs to be further developed. This includes refining the criteria and improving their definitions, selecting the most suitable indicators to measure these criteria, and further developing the scoring system for each criteria. This will involve input and feedback from experts within TNO and externally. We will develop a CETIAS methodology guide that clearly describes the framework and how to use it.

Verification of approach and methodology
The methodology is built on the foundations of background research on publicly available literature, and methods that have been developed to assess readiness levels of technologies, innovations, different types of actor, etc. This is complemented by a small set of interviews with TNO energy transition experts to begin to verify the approach taken and methodology. This verification process will be extended to other experts within TNO, and stakeholders outside of TNO, so that the methodology (the criteria, their descriptions, the indicators, and scoring method) is robust. External stakeholders include policymakers in the Netherlands, different investor types (pension funds, commercial banks, government (related) investment funds), and other researchers and consultants active in the energy transition domain. Together with these partners, we will identify adaptations and additions to the methodology and final CETIAS product.

Validation with specific clean energy technologies
Thus far, the methodology has not been tested by applying it to a specific clean energy technology. Further development involves validating the assessment methodology with a couple of clean energy technologies, and for different types of investor. This will involve working with technical experts to better understand the technology, thus making the assessment credible. This will also involve engaging different types of investor to understand their different perspectives of clean energy technology investment, and how this might impact the results of a CETIAS scan for the same technology. This validation process is a necessary step before applying the methodology on a broader scale.

In addition to the points mentioned above, there are specific aspects of the CETIAS framework that we intend to address. First, the role and use of quantitative data and indicators vis-à-vis qualitative input. Second, how to frame and standardise the section about the outlook for future investment attractiveness of clean energy technologies (see section 4). Third, and finally, how to derive policy insights and recommendations that can stimulate investment into a specific clean energy technology, based on the assessment of the investment attractiveness of that technology using CETIAS.

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