Developing a methodology to track financial flows in the energy system

Financing the Energy Transition in the Netherlands

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1 Introduction

The Netherlands has passed legislation that sets climate goals of 55% emission reductions by 2030 and climate neutrality by 2050, compared to 1990 levels. To achieve this ambition, the government has established increasing targets for sustainable energy: 14% by 2020, 16% by 2023, 42% by 2030, and almost 100% by 2050 (EZK, 2019). To meet these goals, transitioning to a clean energy system needs to happen fast, and will require coordinated action across several domains, including capacity building, institutional strengthening, and financing.

Planbureau voor de Leefomgeving (PBL) has estimated that around €200-300 billion of investment will be needed between 2020 to 2040 in the Netherlands to achieve emissions reduction of 80-95% from 1990 levels by 2050 (PBL, 2020). Given the scale of financial investment required, it is clear that public sources of financing will not be enough to meet climate targets, especially taking into account the competing uses of public funds to address other economic and societal challenges, for example energy security and energy poverty. Although there are recent trends towards increasing public funding to addressing climate change, including the €35bn 'Klimaatfonds' and €20bn 'Nationaal Groeifonds, substantial investment will still need to come from the private sector for the Netherlands to achieve its climate and energy transition targets. The Dutch government has a key role to play in helping to mobilise this private investment at scale and speed.

Public and private institutions investing in the Dutch energy transition need to be able to make efficient and effective investment decisions, which requires a strong, consistent evidence-base. Policymakers are faced with questions such as: How can we finance a successful energy transition that will enable us to meet our climate ambitions? How much funding is needed and when? Where are the investment gaps and how much are these? Which sectors, sub-sectors and technologies need additional policy stimulus? Which financial mechanisms are most efficient and effective to mobilise private sector investment at the required scale, and speed and where should they be targeted? Private financiers are paying increasing attention to the risks and opportunities of the energy transition, and are faced with questions such as: Where do the investment opportunities lie – in which specific sectors, sub-sectors and in which energy technologies? Where and how much are the investment gaps likely to be in the coming years? Where can we best allocate our assets given our risk-return appetite? What are the business cases for investing in sectors, technologies, and in particular specific companies and projects? Currently, there is a lack of consistent, transparent and publicly available data and information on the investment costs and financing of the energy transition in the Netherlands for public and private stakeholders to start addressing these questions.

A strong, consistent evidence-base on investment costs and financing is needed. There have been some efforts to estimate energy system costs and the investment needs of meeting Dutch climate and energy transition targets [PBL (2017, 2018, 2020); ; Kalavasta and Berenschot (2021)], and they provide welcome insight into investment requirements and trends, but they are of limited practical, applicable use to public sector policymakers and private sector financiers. The evidence-base needs to be strengthened, based on a more rigorous, consistent and transparent research, methodologies, data and results, conducted collaboratively with all relevant key stakeholders involved, and independently generated.

This will enable policymakers and private financiers to make better informed, strategic investment decisions.

This report presents the ongoing research being undertaken by TNO at addressing this knowledge gap. Section 2 describes the body of existing Dutch and international (global, regional and national level) studies on estimating investment costs and tracking financial flows towards climate and energy transitions. Dutch studies by Kalavasta and Berenschot and the ‘Interdepartmentale Beleidsonderzoek’ (IBO) are discussed. International studies by the Climate Policy Initiative (CPI), the International Renewable Energy Agency (IRENA), and the International Energy Agency (IEA) at the global and regional level, and the Institute for Climate Economics (I4CE) in France and the Institute for Climate Protection, Energy and Mobility (IKEM) in Germany, at the national level are also discussed. These efforts have informed the development of the methodology for estimating and tracking financial flows in the Dutch energy system. Section 3 describes the first steps, including the scope and considerations, that have been taken towards developing a methodology to track financial flows in the Netherlands, starting with tracking the financing of capital expenditure in energy networks and the power supply sector. Section 4 describes the preliminary results that have been generated from the analysis thus far. Section 5 presents the main challenges and limitations of developing such a methodology, and finally, section 6 provides brief conclusions and describes the next steps for future development of this work.

2 Tracking climate and energy investment and financing: The state of the art

This section describes the state of the art on methodologies developed to track climate and energy system financial flows at a global, regional and national level. Desk research and interviews with CPI, IRENA, IEA, IKEM and I4CE were conducted to identify, understand and learn from the existing state of the art in this research domain.

2.1 Global and regional studies

2.1.1 CPI (Global landscape of climate finance)

Climate Policy Initiative (CPI) is an independent, non-profit organisation with extensive expertise in policy and finance. After the US$100bn climate finance pledge from developed countries to developing countries and emerging economies at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties 15 (COP15) in Paris in 2009, the need for tracking and accountability of global climate investment and financing became apparent. CPI responded to this by developing a global climate finance landscape and has been analysing and tracking global climate finance flows for the past 10 years. CPI's Global Landscape of Climate Finance monitors primary capital flows (public and private) directed towards low-carbon and climate-resilient development interventions with direct or indirect GHG mitigation or adaptation benefits (CPI, 2021c). The insights gained from CPI's global climate finance landscape have informed the UNFCCC Biennial Assessment and Overview of Climate Finance Flows and the technical discussions feeding into the IPCC Assessment Reports.

Over time, CPI's methodology has evolved into a bottom-up methodology that aims to gather data at the project level. Benefits of this data-rich methodology is the high accuracy and level of detail with which insights can be generated, and how this can be connected to individual energy system actors. A drawback of taking this bottom-up approach is its time- and resource intensity. While major efforts were made to collect the necessary data, key data gaps and issues of poor data quality remain.

Whilst the transparency and data availability of finance flows is improving, still little is known about the impact of the climate finance that has been deployed. The reporting mechanisms for public international climate finance are improving, allowing providers to better analyse and prioritise climate financing. However, the private sector, as well as public domestic finance, lack the same level of consistency in reporting, which results in significant data gaps at a less geographically aggregated level. CPI emphasises that there are still many unknowns and data gaps in climate finance, the need for publicly accessible data on climate financing, and that the public, and for the commercial sector to work together to develop a standard definition of climate spending.

To communicate its insights on climate finance, CPI uses various visualisation tools, including Sankey diagrams (see Figure 1). Sankey diagrams are useful tool to graphically represent flows of data, in this case financial data, that could be mixed, separated, and tracked through a succession of events or phases.

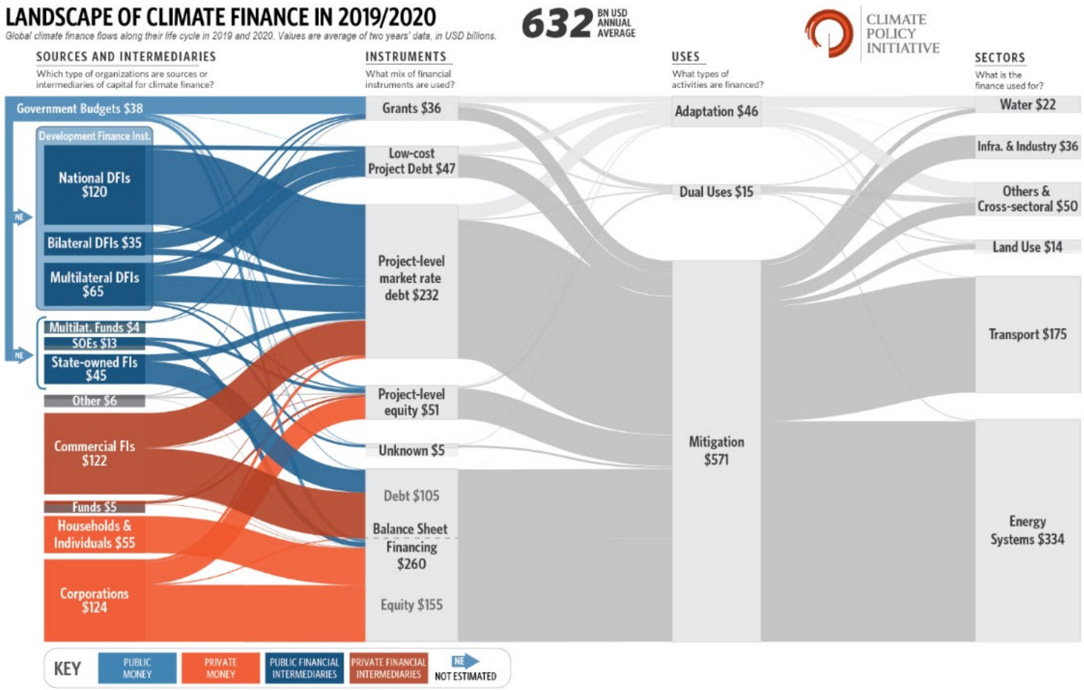

Figure 1: The Global Climate Finance Landscape of 2019/2020 by CPI (CPI, 2022).

2.1.2 IRENA (Global Landscape of Renewable Energy Finance)

The International Renewable Energy Agency (IRENA) publishes an annual report on renewable energy finance. In its 2020 edition, IRENA shows key investment trends, maps out flows from the source (public e.g. governments, climate funds; private e.g. institutional investors, commercial financial institutions) to instrument (e.g. grants, commercial loans, debt and equity) to renewable energy technologies, and the roles different instruments and actors (both public and private) play in the renewable energy finance landscape. The report provides recommendations to policymakers, financial institutions and other stakeholders on how to mobilise investment in renewable energy.

The methodology for developing the Global Landscape of Renewable Energy stems from the approach developed by CPI since 2011 in building the Global Landscape of Climate Finance. The analysis for the report published in 2020 uses a wide range of primary and secondary data sources, and Table 1 below provides an overview of these sources. Since the methodology and utilised data sources are similar to the CPI Global Landscape of Climate Finance, the study by IRENA and CPI faced similar challenges and drawbacks.

Table 1: Data sources used in the IRENA Global Landscape of Energy Finance 2020

Investment type	Source	Data level
Private finance	BNEF (2019a) BNEF (2019b) IJ Global (2019) Weiss and Spörk-Dür (2019)	Project-level (large scale renewable) Aggregated (small-scale solar) Project-level (large scale renewable) Aggregated
Development finance institutions	Surveys* OECD (2019) BNEF** (2019a)	Project-level and aggregated (depending on reporting institutions) Project-level
Climate funds	ODI and HBF (2019) OECD (2019)	Project-level
Governments and their agencies	OECD (2019) BNEF (2019a)	Project-level

(*) This year's report includes primary survey data from 36 DFIs.

(**) Additional data not provided in the surveys or OECD reporting.

2.1.3 IEA (Worlds Energy Investment Outlook)

The International Energy Agency's (IEA) World Energy Investment (WEI) report is its annual benchmark investment and financing analysis across the field of fuel and electricity supply, energy efficiency and energy sector R&D. The target audience consists of governments, investors and other relevant stakeholders. The 2021 report addresses two main questions: 1) if the growing momentum among governments and investors to accelerate clean energy transitions translates into an increase in capital expenditures on clean energy projects; and 2) if the energy investment response to the economic crisis caused by the COVID-19 pandemic will be broad-based, or if some sectors, geographies, and vulnerable parts of the world's population will be overlooked (IEA, 2021). Data analysis generates insights on the progress of capital investment in, and financing of, the energy system, and estimates are made for the near future (a one year time span).

Until 2019, the IEA took an approach of calculating overnight investment in CAPEX. Since then, the IEA has shifted to tracking ongoing investment in CAPEX. For power generation, the investment is distributed evenly from the year in which a new plant or upgrade of an existing plant takes a final investment decision (FID), to the year in which it becomes operational. For other sources, such as upstream oil and gas and liquefied natural gas (LNG) projects, investment is the CAPEX incurred over time as production increases for new sources, or to maintain output from an existing asset.

For energy efficiency, the IEA states that building a methodology is much more complex than for other energy sub-sectors. In WEI 2021, investment in energy efficiency includes 'the incremental spending by companies, governments or individuals to acquire a piece of equipment that is more efficient than the local market average'.

The investment estimates in the WEI are derived from the analysis of IEA data on energy demand, supply, and trade to determine estimates of unit capacity costs (together with industry). IEA thus follows a top-down methodology, much in line with the practice of estimating CAPEX in financial accounting and reporting.

Data on financial performance, financial flows and physical energy changes of assets contribute to strengthening the insights on energy asset turnover. While the data is improving, it is not always available. Due to a lack of source data, balance sheet financing is estimated as the residual of total investment minus the contribution from project finance. While other areas of spending such as operations and maintenance (O&M), R&D, financing costs, Mergers & Acquisitions (M&A) or Public Market transactions are considered important, and are analysed separately, they are not included in WEI.

For WEI the main data sources utilised to estimate project finance levels are IJGlobal[1], the World Bank Private Participation in Infrastructure Database[2], Clean Energy Pipeline[3], and specific transaction announcements.

2.2 National level studies

CPI has, in addition to their global and regional tracking efforts, developed climate finance landscapes for over 15 countries. The focus of these efforts has mainly been on developing countries. Furthermore, the Institute for Climate Economics (I4CE) in France has published an annual French climate finance landscape since 2015, and the German Institute for Climate Protection, Energy and Mobility (IKEM) has developed a climate finance landscape of the German building sector in 2018. These studies are described below.

2.2.1 Developing countries

CPI has developed several Climate Finance Landscapes focusing on developing countries, and wrote guidelines for building a national landscape of climate finance (CPI, 2021). The Landscape of Climate Finance for Kenya (CPI, 2021) is one example of building such a landscape where CPI tracks CAPEX and financing into the climate mitigation and adaptation sectors. CAPEX data were obtained from the Government of Kenya through a standardised template for ministries, counties, departments, and agencies. Secondary data were obtained through National Creditor Reporting Systems for international public finance, Bloomberg New Energy Finance (BNEF) and IJ Global for private sector finance, and the National Treasury for government budget expenditures. The main limitation to the study was the lack of completeness and robustness of data from the private sector.

CPI notes that using different approaches produces sometimes wide variations in results. CPI has mainly tracked CAPEX by accounting for the full investment in the year the financial investment decision was made (as described in section 2.1.3 above). CAPEX can also be apportioned over the years when the investment is expected to be disbursed. The approach taken and impact on results generated should be transparently and clearly described so that the results are interpreted correctly. The difference between these approaches is addressed in this study and described in section 3.4.5 of this paper.

2.2.2 Germany

In 2012, CPI developed the landscape of Climate Finance in Germany (CPI, 2012). This early work of CPI informed the development of subsequent the national climate finance studies in developing countries that are described above.

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[1] IJGlobal | Infrastructure Journal and Project Finance Magazine
[2] Private Participation in Infrastructure (PPI) Database | Public Private Partnership (worldbank.org)
[3] Clean Energy Pipeline

In 2018, the German research institute, IKEM, developed a methodology to track how much CAPEX was made in climate and energy transition measures in the German building sector in 2016 (IKEM, 2018).

IKEM attempted to address the following questions:
- How much investment was made in the energy transition of the building sector in 2016?
- Who were the main investors in this CAPEX and what made these investments possible?
- What financing instruments were the most common?
- What type of measures and buildings were invested in?

IKEM mapped the investments using five elements – sources, intermediaries, instruments, measures and recipients. Sources were either public (national budgets) or private (households and corporations). Intermediaries were ministries, national public banks and capital markets. Instruments were grants, concessional loans or balance sheet finance. The measures identified were either renewable energy, thermal efficiency or electric efficiency. The recipients were types of buildings, such as residential, public and corporate buildings.

The investments tracked were assigned to the year that they occurred, not the year that they were planned. IKEM evaluated data for 2016, while the report was written in 2018. The methodology divides investments in tangible (direct investments) and intangible (R&D and information), and only tangible investments were tracked. Investments can be tracked as total capital investments or incremental costs. For incremental costs, IKEM focused only on additional investments beyond business-as-usual (BAU). Investments that meet the minimum legal standard for construction were considered as the baseline. Additional investments that drive energy consumption down are also included in the research.

The main limitation of the study is that only the current investment volumes were identified. IKEM states that focussing on the investment gap to reach national energy targets instead of only investment volumes is an important step to increasing the usefulness of the results. Even though the results of the study fall within the required investment ranges estimated by other studies, it would be speculative to conclude whether required investment to meet climate and energy transition targets in the sector is on track or not.

2.2.3 France

Since 2014, I4CE has published its annual Landscape of Climate Finance in France. The goal is to provide an economic and financial evidence base in the energy transition in France, both nationally and internationally. The target audience is energy and finance ministers, other Members of Parliament (MPs), and NGOs, and eventually all relevant legislators.

In 2014, I4CE applied CPI's methodology, and although they experienced difficulties in developing best-practices by which to allocate investment across sectors, the work received much government attention. Driven by motivated MPs, legislation was passed stating that parliament has to be informed annually on the state of climate finance in France, and over recent years the research conducted by I4CE has become a tool for policymaking in France. In 2020, a climate recovery plan was being developed by the French government, and the 2020 Climate Finance report by I4CE contributed to the drafting of this plan by government. I4CE started to focus more on identifying and quantifying investment gaps in their reports, and not only on tracing current investment flows.

I4CE's methodology has evolved over the past decade, and currently they track climate investments in the following sectors: energy renovations of houses, transport infrastructure, segregated cycling facilities, low/no carbon vehicles, renewable electricity, biomethane & renewable heat, and nuclear energy. They do not cover the following sectors: energy renovation of tertiary buildings, energy performance of new buildings, industry, agriculture, climate change adaptation, and research & development. I4CE also reports investments in fossil fuels in the following sectors: oil & gas boilers, personal vehicles, business vehicles, aviation, and production & distribution of hydrocarbons.

2.3 Studies in the Netherlands

At least two relevant studies have been published about the financing of the energy transition in the Netherlands. In this section, the methodologies, key findings, and limitations of these studies are discussed.

2.3.1 Kalavasta & Berenschot

Kalavasta & Berenschot (2020) estimated future energy system investment levels with their Energy Transition Model (ETM). The focus is on incremental investments for energy transition i.e. incremental investments compared to a reference situation which reflects the energy system for the year 2020. They provide estimates for years 2020, 2030 and 2050. For rebuilding the energy system of 2020 about €350 bn in total is needed. Until 2030 the technical target ('projection') of the Dutch Climate Agreement has been used, without considering policy measures i.e. without subsidies, standards, and pricing. For the time period 2030-2050 an average scenario of the four Integral Infrastructure II3050 energy system scenarios has been used. This results in incremental energy system investments of €112 bn until 2030 and €355 bn until 2050 respectively.

Investment estimates have been performed for the following sectors:
- Central production
- Network infrastructure
- Built environment
  Mobility
- Industry
- Agriculture.

Subsequently, the study discusses the bottlenecks for financing of these investments. They distinguish four generally applicable factors and analyse these:
1. The unprofitable gap of the investment. Their analysis is based upon expert-based estimates i.e. no detailed business case analysis has been undertaken
2. The creditworthiness of the borrower
3. The available liquidity i.e. the time horizon of the investment
4. Assessment criteria for lending. Bottlenecks identified include the technology being insufficiently mature, insufficient cashflow return combined with a long depreciation period, cash flow uncertainty, large upfront investment and long duration, and a low value of the underlying collateral.

Based upon an expert judgement assessment, the study concludes that nearly half of the required additional €355 bn of incremental investments until 2050 probably cannot be financed without additional measures. They recommend to include an overview and analysis of incremental investments in the yearly national climate and energy projection (KEV). When assessing whether emission reduction targets for a certain year will be achieved, financing issues should be an integral part of the analysis.

The analysis is based upon a generic top-down model with several limitations. Sector-specific bottom-up models allow for more accurate estimates of future investments and financing needs. It does not present a methodology to track financial flows, but rather uses raw expert-based estimates to come up with general estimates of required financial means.

For several reasons, the need for investments, and therefore financing, seems exaggerated:

- When estimating whether there is an unprofitable gap, and when assessing the creditworthiness of parties, taxes (energy tax or CO2 pricing), standards, and subsidies (such as the SDE++ subsidy scheme, which covers the unprofitable gap for a range of CO2 reducing technologies) are not taken into account. This affects the extent to which sectors in reality will face financing issues.
- Current cost levels are assumed i.e. no cost reductions due to learning effects in 2030 and 2050 are assumed.
- The regulated nature of grid operators (e.g. electricity, natural gas) is not accounted for, while this greatly reduces risks for financiers and therefore the investment at risk.
- The study assumes that all investments must be realised regardless of the creditworthiness of actors. In practice, this financing issue can largely be overcome by planning larger amounts of investments than is required. Such an approach takes into account that part of the investments cannot be financed, but at the same time the goals are achieved.

2.3.2 IBO Financiering Energietransitie: Beleidsmatige keuzes in kosten, prikkels en verdeling [Interdepartmental Policy Study Financing Energy Transition: Policy choices in costs, incentives and distribution]

The study surveyed financing of the energy transition from the end-user cost perspective. This perspective is closely linked to the national cost perspective. National costs or integral system costs are the direct costs and benefits for Dutch society. They include not only investments costs (given the accounting framework through yearly depreciation), but also O&M costs and energy costs. They do not include subsidies and taxes (or tax losses) since these are considered as transfers (redistribution of money across Dutch stakeholders).

End user costs are the costs for the consumer or end-user of buying a product or service (where the end-user could also be a firm). These costs are derived from national costs, and cost allocation mechanisms such as taxes/retributions, network tariffs, subsidies and profit margins of producers are taken into account.

The essay proposes changes to:

- Improve the effectiveness of existing policy instruments such as European and national CO_2 pricing (including reducing degressivity, reduced rates and exemptions of energy taxes and levies).
- Achieve coordination from the national government to facilitate necessary investments in heat and hydrogen infrastructure.
- Change cost allocation of climate policy through partial replacement of energy-specific means by general funds as well as provide targeted subsidies in the built environment.

The essay concludes that realisation of the climate targets is only possible with large and timely investments in the energy system, and guarantees and subsidies are needed to achieve the required investments in heat and hydrogen infrastructure as well as in the built environment.

There are some limitations to the study, including:

- Attention for the tracking of financial flows between actors is limited. It does not provide insight on who should finance private investments, the proportions of debt and equity, and the financing providers involved.
- The main focus of the study is on energy bills for households and firms, although it is recognised that investments of households and firms are not visible on energy bills and will increase substantially in the coming period. Tracking financial flows would be complementary as it would provide a more comprehensive picture of the financing issues faced by energy sectors and consumers.

The main studies that have explored the tracking of financial flows and quantification of investments in energy systems and climate change have been discussed in this section. Section 3 describes the first steps in building a methodology to estimate and track financial flows in the energy system in the Netherlands.

3 Towards developing a methodology for the Netherlands

This section describes the first steps and considerations taken in developing a methodology for tracking financial flows in the Dutch energy system. The section begins by describing a framework for tracking energy system investment costs, based on the desk research described in section 2 and expert interviews. The energy system architecture that the methodology is based upon is then introduced, which is the technology-rich bottom-up energy system optimisation model, OPERA (Option Portfolio for Emissions Reduction Assessment), and the reasons for choosing this architecture are given. The scope and specific methodological considerations for energy networks and the power supply sector are then described.

3.1 The Framework

In this section we describe an overarching framework for developing an energy system financial landscape in the Netherlands, based on the state-of-the-art studies conducted at a global, regional, and national level, as described in section 2 of the paper. The following components are prominent across these studies:

- Sources of capital: these can be either public, for example the EU or Dutch Ministries, or private, for example commercial banks, financial funds, companies, project developers, institutional investors or households.
- Intermediaries: Public sources of capital typically distribute that capital through public financial intermediaries, such as RVO (the Dutch Enterprise Agency), Groeifonds, or the Innovation Fund in the Netherlands. They also distribute capital through commercial banks or public-private intermediaries such as InvestNL or BNG (bank for financing Dutch publicly owned organisations). Private sources of capital also sometimes use public-private intermediaries.
- Financial instruments: Public sources of capital provide capital through grants, levies, taxes and concessional lending, while private sources of capital invest either through project finance or directly on the balance sheets of companies. Project and balance sheet finance are provided as debt or equity (or variations of these two instruments).
- Recipients: These are, for example, project developers, companies, private individuals or households.

Figure 2 shows the general overarching framework, which includes these core components.

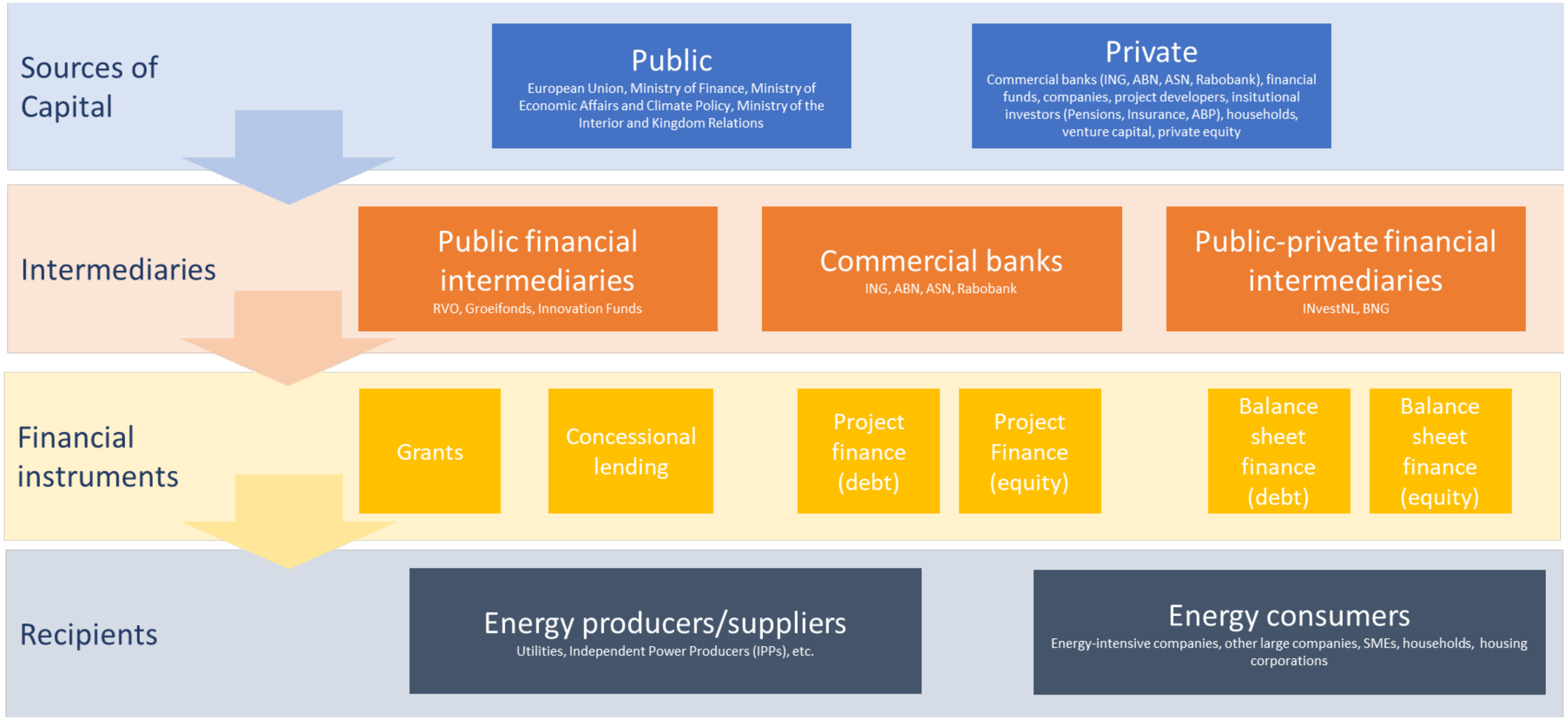

Figure 2: A framework for developing a landscape of energy system financing for the Netherlands.

3.2 The energy system architecture

The OPERA model is a tool for integrated energy systems analysis for the Netherlands. The model has been applied in several Dutch research projects over recent years, and is used mainly for three purposes: formulating policy advice, providing insights into the role of different groups of technologies in meeting climate and energy targets, and analysing the effects of different energy system compositions over space and time (van Stralen et al., 2021).

There are three main reasons why the OPERA energy system architecture is chosen as the basis for building the methodology to track financial flows in the Dutch energy system. First, the model covers the entire energy system and all greenhouse gas emissions of the Netherlands (van Stralen et al., 2021). Aligning financial flow tracking with such an energy system model that has been used extensively to formulate strategic policy advice for the Dutch government on decarbonising the energy system, provides a strong foundation from which to develop useful insights, such as identification of (future) investment gaps in specific areas (sector, sub-sectors, technology specific) and the size of these gaps. Second, OPERA models the energy system in detail and is aligned with modelling tools that are used for the Dutch National Climate and Energy Outlook (KEV). Third, and finally, the energy system architecture in OPERA has been built using expert knowledge of energy systems, and provides a pre-defined scope and boundary conditions between different sectors and different technologies. Using existing architecture provides consistency, continuity, can help to increase transparency in data, analysis, and the results, helps to prevent unintentional exclusion of specific types of investments, and to avoid double counting of investments across sectors.

The following two sections discuss the scope of work and main methodology considerations for tracking the current investment flows in energy networks and storage and the power sector respectively.

3.3 Energy networks: Scope and considerations

The sector in OPERA is called ‘energy networks and storage’, but energy storage is excluded due to its diverse characteristics, relatively small sized investments (natural gas and hydrogen storage could be considered exceptions), and different structure than energy networks. There are different types of energy storage: electricity, gas, and heat storage. Electricity storage (using batteries) is currently limited in the Netherlands[4]. Furthermore, in contrast with electricity networks, electricity storage can be involved in multiple different business cases with varying types of risks, and thus different financing requirements. Business cases for electricity storage include electricity trading (profiting from price arbitrage), system balancing (provision of balancing products that require strong ramping capabilities such as Frequency Containment Reserves (FCR) and Frequency Restoration Reserves with automatic activation (FRR)), and deferral or avoidance of investments in network expansion. In contrast with electricity storage, both gas and heat storage involve larger amounts of energy, and typically larger financial flows. Electricity, gas and heat storage require substantially lower levels of investment than energy networks. Additionally,

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[4] This could change in the near future though, since there are many plans to install electricity storage. For example, in the Southern provinces TenneT received connection requests for 300 MW of battery storage. See https://energeia.nl/energeia-artikel/40102510/jetten-komt-met-crisisaanpak-voor-zuidelijke-netproblemen

heat storage are included in the scope of the industry and agriculture sectors, which could be addressed in future research efforts in this domain.

Energy networks are defined here as electricity and natural gas networks. Heat, hydrogen and CO_2 networks are currently not as widely deployed and more locally oriented and therefore are not considered as part of the current scope.

Investments in energy networks

Two public sources for investments in electricity and natural gas networks are identified:

1. Network investment plans of public network operators. Each network operator is legally obliged to publish a network Investment Plan (IP) every two years with a 10-year time horizon. The basis for the investment plans is article 21 of the Electricity law 1998.[5] Legal requirements are detailed in secondary legislation (Algemene Maatregel van Bestuur, AMvB, and Ministeriële Regeling, MR).[6]
2. Regulatory Asset Base (RAB) calculations for TenneT, Gas Transmission Services (GTS), electricity Distribution System Operators (DSOs), and gas DSOs respectively. These calculations are published by the Dutch national regulatory agency of electricity and natural gas networks (part of Authority of Consumers and Markets, ACM) for each regulatory period (currently 4 years). Most recent calculations originate from 2021.[7] As part of these calculations, network investments figures are published for a number of asset categories which are sliced based upon depreciation periods.

The main difference between these two sources is that network operators publish the investments at the time of spending, while ACM publishes the costs at the time of commissioning (the latter cost figures include financing costs during construction). Network investments are increasing over time due to the infrastructure upgrades needed for a successful energy transition, which means that for recent years the investment figures of network operators are likely to be higher than ACM's calculations, and a more accurate indication of current CAPEX. Brattle (2021) notes that this is only due to timing, since all planned CAPEX will be eventually included in the RAB. A limitation of the ACM data is that envisaged investments of the category *Rijkscoördinatieregeling* (RCR) are not part of the public RAB calculations for TenneT. This could be because of TenneT procurement conditions, for example no disclosure of investment amounts before the tendering process has finished, in order to prevent strategic behaviour of tenderers. Realised RCR investments, however, are reported for the most recent year in the ACM assessment of the yearly network tariff proposal of TenneT (ACM, 2021). Since the network investment plan figures include RCR investments not only for the most recent year but for all years, these figures are deemed to be the most representative for both the current situation and the near future, and thus these are used to identify financial flows.

The investment plans published in 2020 (IP, 2020) were reviewed at the start of this study to obtain network investment figures, apart from the network investments of DSO Enexis, which are reported in a confidential annex to their investment plan. For Enexis both their annual

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[5] https://wetten.overheid.nl/BWBR0009755/2021-07-01#Hoofdstuk3_Paragraaf3_Artikel21

[6] wetten.nl - Regeling - Besluit investeringsplan en kwaliteit elektriciteit en gas - BWBR0041487 (overheid.nl); wetten.nl - Regeling - Regeling investeringsplan en kwaliteit elektriciteit en gas - BWBR0041543 (overheid.nl).

[7] For TenneT: https://www.acm.nl/sites/default/files/documents/gaw-berekening-tennet-voor-de-reguleringsperiode-2022-2026.xlsx
For GTS: https://www.acm.nl/sites/default/files/documents/berekening-gaw-bij-x-factorbesluit-2022-2026.xlsm
For regional DSOs electricity: https://www.acm.nl/sites/default/files/documents/gaw-bestand-regionale-netbeheerders-elektriciteit-2022-2026.xlsx
For regional DSOs natural gas: https://www.acm.nl/sites/default/files/documents/gaw-bestand-rnb-gas-2022-2026-sector.xlsx

report and annual network plan were reviewed. In the meantime, new investment plans (IP, 2022) have been published (April 2022), with the exception of the TenneT onshore investment plan which requires adjustments following ACM’s assessment (ACM 2022a, 2022b). TenneT published an adapted version on 1 July 2022. The most recent IP 2022 investment figures are also included in this study.

3.4 Power supply: Scope and considerations

The sector in OPERA is called ‘energy supply’, but the scope for this study is power (electricity) generation only, mainly due to relatively good data accessibility and availability for the power sector, and due to insufficient project resources to be able to cover the entire energy supply sector in the scope of this initial study.

The following key steps have been taken:

1. Determine the power generation technology groups.
2. Determine the annual installed capacity for each technology group for each year between 2010 and 2020.
3. Determine the annual investment cost per MW for each technology group for each year between 2010 and 2020.
4. Calculate the total annual CAPEX investment for each technology group by multiplying the annual installed capacity by the annual investment cost for the year 2020.
5. Divide the total investment cost across public and private sector sources, balance sheet and project finance, and debt and equity, for each technology group for the year 2020.

The first three steps are performed for the period of 2010 to 2020. The fourth step is performed only for the year 2020 to provide a snapshot of the financial flows in the power supply sector for that year.

Sections 3.4.1 to 3.4.6 discuss several key considerations that were taken into account when estimating the financial flows for the power sector.

3.4.1 Technology groups

The following technologies are included in the scope of this study: Wind onshore, wind offshore, solar PV field, solar PV roof, hydropower, biomass co-firing, biomass standalone, gas, coal, nuclear, and waste incineration.

Onshore and offshore wind are separated because investment costs per MW differ significantly, and the ratio of debt to equity varies between these two technology groups. Solar PV deployed in fields and solar PV deployed on roofs are also separated for these reasons. Hydropower is included in the analysis, but the total cumulative installed capacity is low relative to other technologies (37 MW). Biomass technologies are divided into two groups, co-firing and standalone. Co-firing biomass is a recent technology development deployed in coal plants, and has a different investment cost per MW than other biomass technologies. The biomass standalone technology group bundles together different types of biomass combustion (thermal conversion) with the following categories of biomass boilers: solid and liquid biomass boilers, B-grade (scrap) wood boiler, wood pellet steam boilers, direct use of wood pellets for industrial applications, and large wood pellet boilers for district heating (RVO, 2020). Biomass combustion produces both renewable heat and renewable electricity. Based upon figures for biomass combustion for electricity and heat by firms from CBS, 2022, it is assumed that 75% of the output of biomass combustion plants is for renewable heat and 25% for renewable electricity. Hence, 25% of the installed generation capacity is assumed for renewable electricity production from the biomass standalone category. Investment cost figures for both co-firing and biomass standalone combustion plants originate from PBL, 2019. Furthermore, conventional power generation technologies such gas, coal, nuclear and waste incineration are included to provide a complete overview of investment costs in the power supply sector.

3.4.2 Installed capacity

The annual cumulative installed capacity for the period 2010 to 2020 is determined for each technology group, and is shown in Figure 3 below. The data sources used and decisions on what is included and excluded in the scope are as follows:

- Publicly available data from CBS is used for wind onshore, hydropower, and coal.
- Installed capacity of individual offshore wind farms is combined to calculate the total for offshore wind.
- SDE++ datasheets on actualised projects are used for solar PV field, solar PV roof, biomass co-firing, biomass standalone, and waste.
- Field-based projects and water-based projects (lakes and dikes) are included in scope for solar PV field.
- Roof-based projects and projects without a specification are both included in scope for the solar PV roof technology group.
- Projects designated as biomass large are included in biomass co-firing, while biomass combustion projects are called biomass standalone.
- Data from the Dutch national Climate and Energy Outlook 2022 (Figure 4.4 of the Outlook) is used for the technology groups natural gas and coal.
- The installed capacity of the Borssele nuclear power plant is used for nuclear.

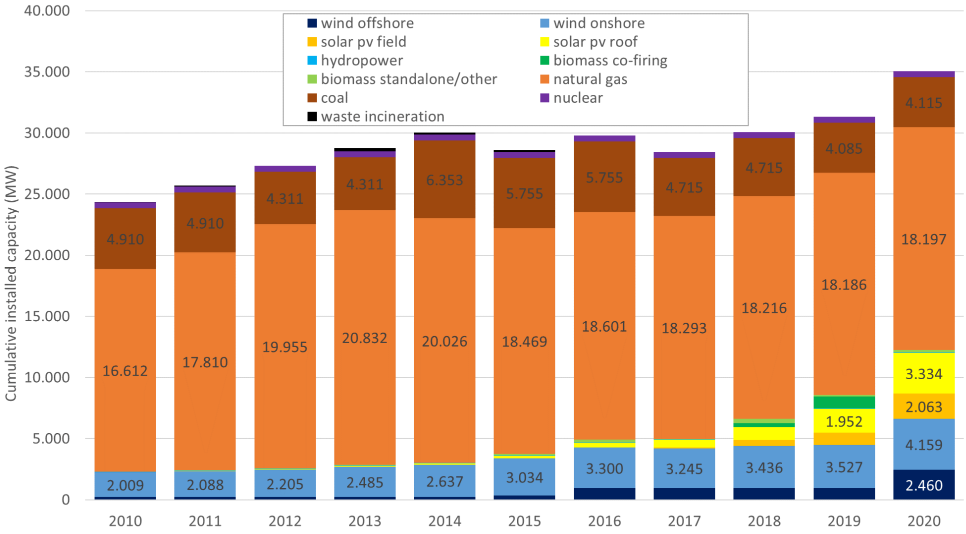

Figure 3: Cumulative installed capacity in the power supply sector in the Netherlands.

The annual incremental installed capacity is the difference in cumulative installed capacity from one year to the next, and is shown for the years 2010-2020 in Figure 4 below. In years 2014, 2015, and 2016 new coal plants came online and some were decommissioned. The incremental installed capacity is adjusted to reflect the decommissioning that took place between 2014 to 2017. CBS does not provide the breakdown of installed capacity of the new coal plants, therefore the installed capacity for these plants is taken from the S&P World Electric Power Plants database. There is a slight discrepancy between the annual installed capacity reported by CBS and S&P, which is probably due to the timing of the decommissioning of the coal power plants.

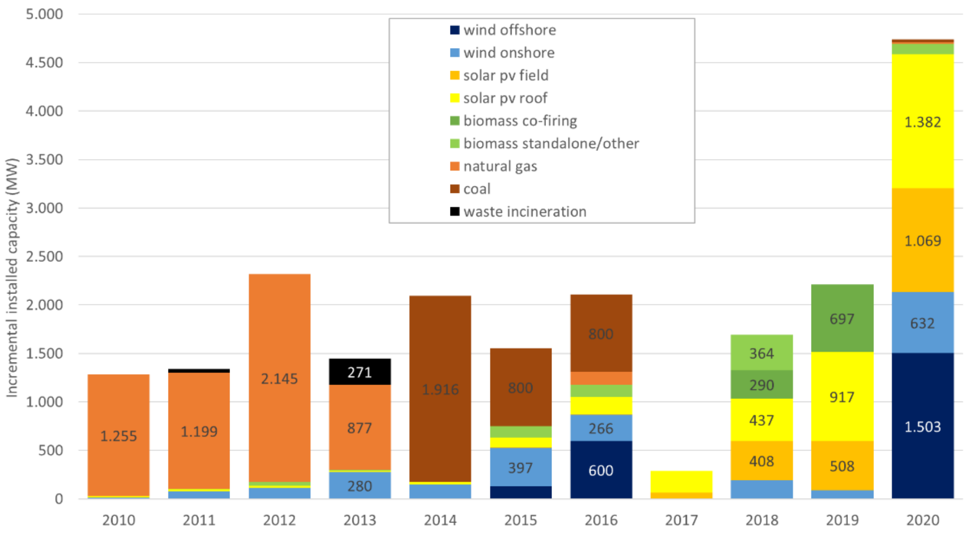

Figure 4: Incremental installed capacity in the power supply sector in the Netherlands.

3.4.3 Investment costs per unit of power

Annual average investment costs per unit of power for each technology group have been collected from various sources. Figure 5 below shows the average investment costs in nominal euros per kW from 2010 to 2020 for all of the technologies covered in this study. Where possible, for some technologies, we have also collected investments costs back to the year 2000, but these are not shown in Figure 6.

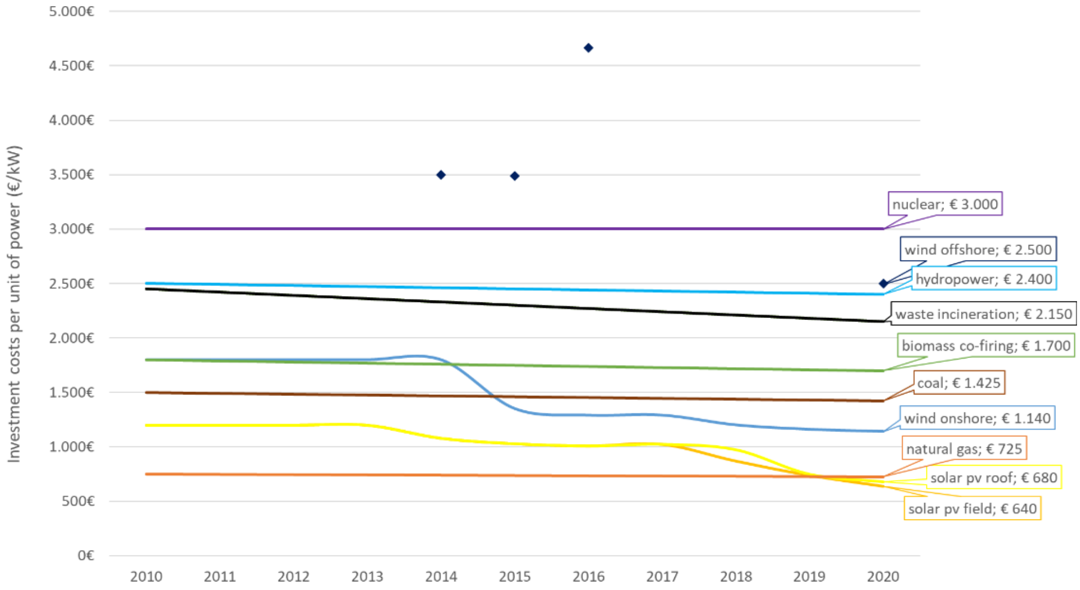

Figure 5: Investment costs per unit of power for each technology group for the period 2010 to 2020.

Investment cost data is taken from the publicly available SDE++ *'onrendabele top model'* which contains a summary of the quantitative assumptions applied for the calculation of technology-specific subsidy levels for a range of renewable energy and other CO_2 emission reduction technologies in the SDE(+)(++) subsidy scheme. These investment cost figures have been used for the technology groups wind onshore, solar PV field and solar PV roof. PBL determines these amounts based on investment data from realised projects, modelling tools to account for learning and cost-inflation effects, and expert interviews across the renewable energy sector. Publicly available data on installed capacities and investments costs of realised offshore wind farms is used for the technology group offshore wind. For the technology groups of hydropower, biomass co-firing, biomass standalone, natural gas, coal, nuclear, and waste, data from the PBL investment cost overview has been used. This investment cost overview is based on the IEA Projected Costs of Generating Electricity 2015 report, and is used in the COMPETES model (euros in 2015), COMPETES is an electricity system model developed by TNO and PBL, which is used to provide input to the Dutch Climate and Energy Outlook. In 2020, the IEA published an update of the Projected Costs of Generating Electricity, which will be accounted for in upcoming versions of the COMPETES model.

As is shown in Figure 5, investment costs for conventional power generation technologies, such as coal and gas, have remained relatively stable between 2010 and 2020 compared to some renewable energy technologies. Investment costs for solar PV roof and field, as well as wind onshore and offshore, have declined the most, which is consistent with global trends in investment costs for these technologies.

3.4.4 Construction period and lifetime

The average construction period for projects differs between technologies, as is shown in Table 1 below, ranging from 0 to 7 years. For the purpose of this study, the investment cost per unit of power generated at the beginning of the project construction period is used, rather than when the project became operational. The main reason for taking this approach is that significant cost reductions have occurred in several technology groups, especially renewable energy generation technologies such as solar PV and wind. Investment costs per unit of power are higher for these technologies when the project construction period began, and these technologies require large CAPEX investments to be made upfront. Using current investment costs per kW would thus result in an underestimation of the total investment costs. An example is the construction time for onshore wind projects, which is assumed here to be 1 year on average. A project that became operational in 2018 would use the investments costs of onshore wind for the year 2017 (1290 €/kW) rather than 2018 (1200 €/kW), which would be €90/kW lower that when the project construction phase began.

The average lifetime of a project for each technology group is needed to estimate investment costs on an annualised basis (see the following section 3.4.5, which considers calculating annualised versus overnight investment costs). This study uses average lifetimes of projects from the IEA Projected Costs of Generating Electricity 2020 report. For the technology groups biomass co-firing, biomass standalone, and waste incineration, the lifetime for coal power plants is used as a proxy.

Table 2: Lifetime and development time for each technology group.

	Average project lifetime [years]	Construction period [years]
wind onshore	25	1
wind offshore	25	2
solar PV field	25	1
solar PV roof	25	0
hydropower	80	5
biomass co-firing	40	4
biomass standalone	40	4
natural gas	30	3
coal	40	4
nuclear	60	7
waste incineration	40	4

Note: The construction period for wind offshore is 2 years in the table. Data on the investment costs of individual offshore wind farms is available, so the adjustment for this technology group was not required.

3.4.5 Overnight versus annualised investments

Tracking financial flows into power generation technologies can be undertaken in different ways. Investments can be accounted for in the year that a financial commitment is made, for example when the final investment decision is reached by the board of directors of a company. This approach is taken by IEA (2015) and IEA (2020) and was taken by IRENA in their development of the Global Landscape of Renewable Energy Finance 2020, and can be referred to as the *overnight investment* approach. This approach was also taken in the analysis of energy networks in the previous section of this paper.

An alternative approach to accounting for investments is to divide the total capital investment in a project over a specified time period. This approach prevents high volatility in the reported numbers, notably for sectors such as the power sector which is characterised by large asset deployments in single calendar years. IRENA describes this as the *annualised investment* approach in their Global Landscape of Renewable Energy Finance 2020. It is also in line with the national cost and end-user cost approaches that are applied for ex-ante policy assessment in the Dutch context (Rijksoverheid, 2021). For the purpose of this study, to calculate the annualised investment across different technology groups, the overnight investment is evenly distributed over the years of the average lifetime of a project in that technology group. The difference in the results generated between these two different approaches are shown in section 4.

3.4.6 Other key assumptions to estimate financial flows

Several other key assumptions have been made to determine the amount of finance flowing from sources of capital to power generation technologies. These assumptions are described below and shown in Table 2.

Private versus public funds

Investments in renewable electricity are mainly financed by private funds. Steffen (2018) states that in Germany 85% of 2012 investments in renewable power generation have been made by institutional and strategic investors, and private individuals. Given that in the past 10 years wind and solar PV have become mainstream power generation technologies with lower investment risks, public funding in Germany and other Western European countries has declined. In this study, very limited information was found about public investments in renewable power generation assets in the Netherlands. One exception are provincial and municipal funds that provide subsidies and loans to energy cooperatives for the financing of small scale wind and solar PV projects (e.g. Hier & RVO, 2022). The amount of public financing of CAPEX of renewable power generation assets appears to be minimal, and thus for the purpose of this study we have focused on analysing only financing flows from the private sector.

Project versus balance sheet finance

Project developers can finance a project either through balance sheet finance or project finance. With balance sheet finance, capital is raised at the company level. Debt providers assess whether the company is able to repay the debt, and equity providers assess whether the company will make enough profit to generate the required rate of return (PwC, 2020). With project finance, capital is raised at the project level. The project developer attracts financing (debt and equity) to fund the investment, financiers are repaid from the cashflows of the project, and the finance is non-recourse, meaning that in the event of a default, the financiers have no legal rights to claim the assets of the project's owners. To secure project financing, project developers must meet the financiers requirements to mitigate risks (e.g. undertake extensive due diligence).

According to the BNEF Renewable Energy Investment Tracker, 2H 2022, 90% of global renewable energy investment is funded by project finance and 10% by balance sheet finance. Project finance is increasingly deployed, notably by independent project developers, to grow their wind and solar project pipelines. In this way, they can increase their leverage ratio and utilise their equity for as many projects as possible, enabling project developers to finance more projects than their company balance sheet would otherwise allow (Steffen, 2018). At the same time, given its non-recourse nature, project financing requires banks to be relatively more familiar with projects when providing debt. This means that first-of-a-kind projects are often financed by balance sheet financing, but once understanding about technology risk increases, project financing will develop and become the most frequently used way of financing a project (PwC, 2020).

Public information about the shares of project and balance sheet financing by renewable energy technology is lacking. Below are some estimates for the project finance to balance sheet ratio for different power generation technologies. As literature on this topic is limited, these estimates are largely based upon expert judgement:

- *Offshore wind:* In Europe project financing is common, with an average share of project financing to total investments of 90% in years 2016-2019 (PwC (2020), Figure 4). Hence, we assume a 90/10 project finance to balance sheet (PF/BS) ratio for this technology.
- *Solar PV:* A distinction can be made between ground based solar PV and solar PV on rooftops; solar PV on rooftops can be financed privately by a homeowner, on the balance sheet of a company who is the building owner, or from an intermediary such as an Energy Service Company (ESCO) (60/40 PF/BS ratio), while ground-based solar PV is typically financed on a project basis (90/10 PF/BS ratio).
- *Natural gas, coal, and nuclear power plants:* These are large investments that are likely to be ringfenced (i.e. guaranteed that the funds are spent only for the purpose of the project) from other activities for risk management purposes, and thus project finance is common (80/20 PF/BS ratio).
- *Waste:* Given that waste incineration can be part of integrated processes of waste companies, balance sheet financing seems most likely for this technology (20/80 PF/BS ratio).
- *Other technologies:* Given a lack of information, for biomass standalone (i.e. biomass combustion), and hydropower it is assumed that the financing is sourced in equal proportion between on balance sheet and project financing (50/50 PF/BS ratio).

Debt/equity ratio

SDE++ advices from 2020 for the wind onshore, solar PV field, and solar PV roof technology groups assume project finance, and therefore primarily provide insight into the debt to equity ratio for project finance. For balance sheet finance, debt to equity ratios in this study are assumed to be the same as in project finance, but in practise could be significantly lower. For the offshore wind farms the gearing ratio is based upon the average debt /equity ratio of 75/25 for recently realised individual offshore wind farms, as mentioned by PwC (2020). For all other technology groups, this study makes an assumption of an 80/20 for the debt/equity ratio, which is based on own expert judgement.

Table 3: Input values for each technology group

	Private finance					
	Balance Sheet	Project	Balance Sheet Debt	Balance Sheet Equity	Project Debt	Project Equity
Wind onshore	45%	55%	80%	20%	80%	20%
Wind offshore	45%	5%	75%	25%	75%	25%
Solar PV field	45%	55%	85%	15%	85%	15%
Solar PV roof	45%	55%	85%	15%	85%	15%
Hydropower	45%	55%	80%	20%	80%	20%
Biomass co-firing	45%	55%	80%	20%	80%	20%
Biomass standalone	45%	55%	80%	20%	80%	20%
Natural gas	45%	55%	80%	20%	80%	20%
Coal	45%	55%	80%	20%	80%	20%
Nuclear	45%	55%	80%	20%	80%	20%
Waste incineration	45%	55%	80%	20%	80%	20%

The next section describes the preliminary results of this study, based on the inputs and key considerations discussed here in section 3. Some of the results are based on calculations that lack a strong evidence base, and rely heavily upon expert judgement. Further research is required, and will be carried out in 2023, to gather additional data, refine assumptions and the methodology, and develop a stronger evidence-base upon which to generate improved results, in particular for the power sector.

4 Preliminary results

This section is divided into two parts. Section 4.1 shows the results of analysing publicly available data to estimate investment amounts and financial flows in energy networks in the Netherlands. Section 4.2 shows the results of analysing mainly publicly available data to estimate investments and financial flows in the power supply sector in the Netherlands.

4.1 Energy networks

This section describes the financial flows from sources to recipients in energy networks. Investments in energy networks between 2020 and 2022 are analysed, as well as how these investments are financed and who has provided this finance.

4.1.1 Investments

Figure 6 shows the investments in electricity grids, based upon a review of the IPs of network operators. In the table, the investments of each network operator are shown. A distinction is made between Transmission System Operators (TSO) TenneT (striped blocks) and DSO investment levels. No private investments are shown, although in practice limited private investments are made in electricity networks of closed distribution systems of companies or industrial estates. In terms of investment costs, these costs are relatively small. For example, to connect a private grid and transformer for 500 MW of solar power to the high voltage grid of TenneT costs € 10 million.[8] To connect new renewable generation (while DSOs cannot provide timely and regular network connections), private grids could be utilised more extensively in the future.

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[8] See: https://energeia.nl/energeia-artikel/40102340/acm-stemt-in-met-aanleg-privaat-net-voor-500-mw-aan-zonneparken-in-groningen en https://energeia.nl/energeia-artikel/40102444/privaat-net-verlicht-problemen-regionale-netbeheerders

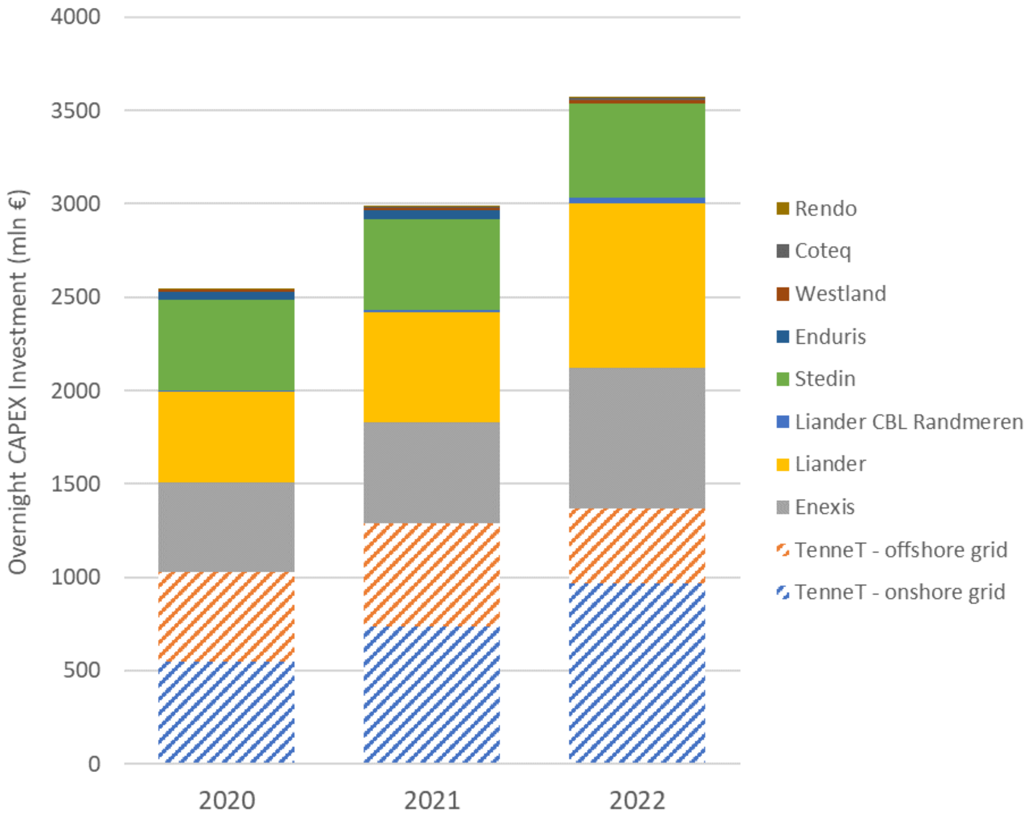

Figure 6: Overnight investments in electricity networks in the Netherlands 2020-2022.

The total investment in electricity networks roughly amounts to about €2.55 bn in 2020, with largest investments made in distribution networks i.e. networks operated at voltage levels below 110kV. Total investments are slightly higher than the approximately €2.2 bn in 2020 that is mentioned by PwC in its report on the financial impact of the energy transition on network operators (PwC, 2021).[9] This difference relates to different choices made in this analysis compared to the PwC study:

1. In this study, the investments of all public network operators are identified. PwC has only identified the investments of the largest network operators (i.e. TenneT, Enexis, Liander and Stedin). This difference amounts to about €68m in 2020.
2. Gross investments including (private) customer contributions (e.g. for Enexis, no net investments amounts are available) are sometimes taken into account, while PwC provides a total net amount from which customer contributions have been deducted. Enexis (2020) states that these contributions amount to €114m for electricity and gas together in 2020.
3. This assessment does not completely correct for the costs of investments in smart meters, since investment amounts excluding smart meters are not always available in the IPs. PwC corrects for all smart meter investments.

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[9] Inferred from sheet 44.

Furthermore, precise investment amounts are sometimes not provided, and can only be roughly derived from graphs and charts (e.g. for TenneT).

Figure 7 shows the investments in natural gas grids, based upon our own review of the IPs of network operators. In the table, again a distinction is made between TSO (striped blocks) and DSO investment levels.

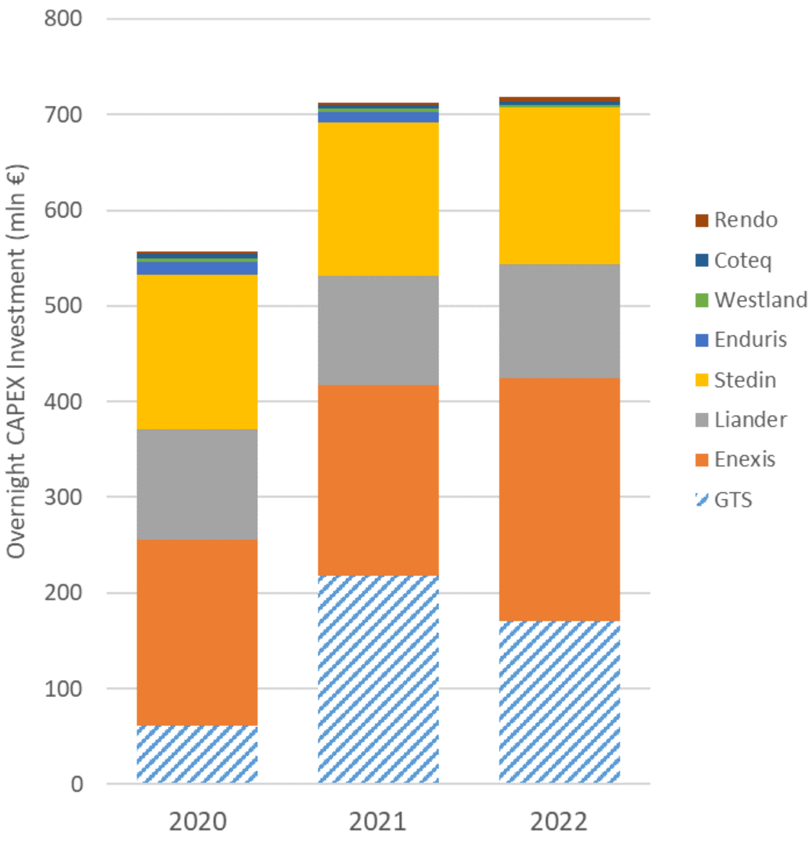

Figure 7: Overnight investments in natural gas networks in the Netherlands 2020-2022.

The total amount of investments in natural gas networks amounts to about €550m in 2020. This is higher than the approximately €375m in 2020 that is stated in the PwC report[10], but it excludes TSO GTS investments of €61m in 2020. The remaining difference results from different choices made, which have already been outlined in the electricity part above. These relate to 1) the analysis of all network operators instead of the largest network operators only; 2) the inclusion of customer contributions in investment cost figures of a number of network operators; and 3) the inclusion of smart meter investments in investment cost figures of a few network operators. Besides, the PwC total investment cost figure for 2020 is presented as a projection, while the investment costs in this study are realised figures from IP 2022.

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[10] Inferred from sheet 45 of the PwC report.

4.1.2 Financing – Need for debt and equity

Network investments need to be financed, and network operators borrow part of their investments (debt) while the remaining part is financed by equity, which comprises in part retained earnings and in part external shareholder capital. The associated debt and equity portions are derived from financial statements of network operators (as reported in the S&P financial database).[11] Company-specific debt/equity ratios[12] were calculated and these were translated into company-specific gearing levels. Gearing refers to the extent to which a company is financed by debt, expressed as a fraction of total assets. Gearing levels range from 35% (34%) for GTS to 60% (58%) for TenneT in 2020 (2021). Figure 8 provides an overview of the resulting debt to equity distribution for the network operators. The main conclusion is that with increasing investments over time, both debt and equity providers need to provide more funding, notably to electricity network operators.

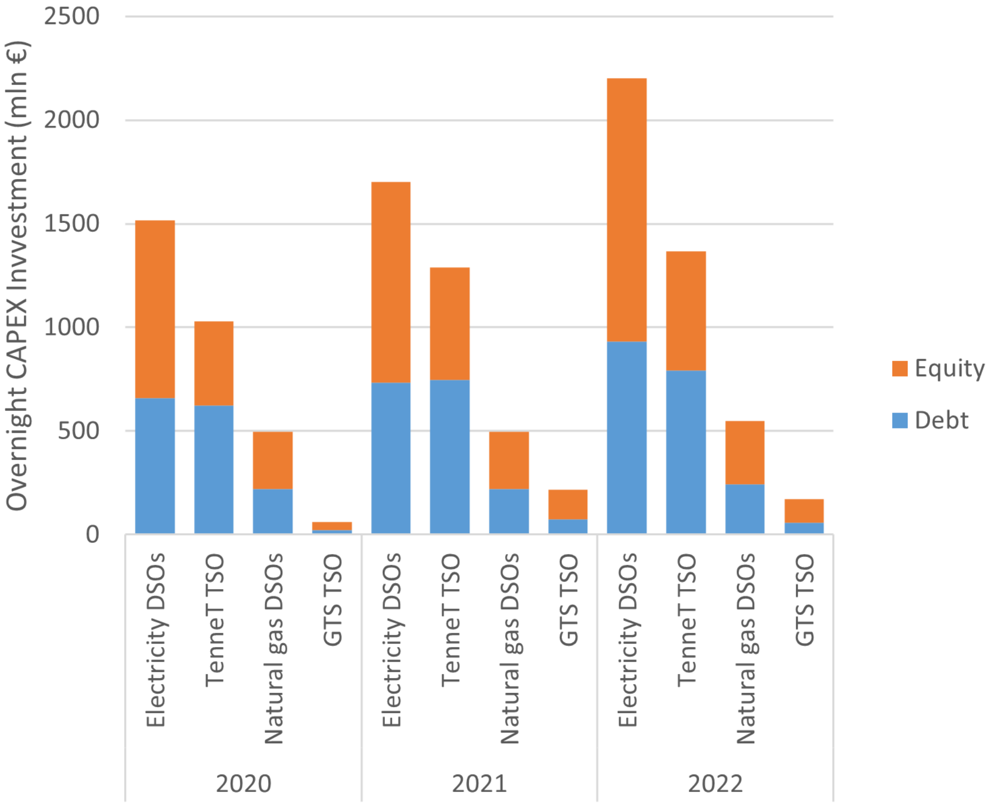

Figure 8: Debt-Equity distribution for Dutch TSOs and DSOs

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[11] ACM (2021) follows a different approach. They assume a so-called notional gearing level i.e. the actual median gearing level of the peer group of foreign firms rather than the actual gearing levels of the regulated network operators.

[12] Following ACM (2021) we assumed net debt. S&P defines net debt as total senior debt of company less total cash and short-term investments. For equity we assumed total common equity i.e. book value attributable to common shareholders plus total minority interest (the latter is only reported for TenneT). Data was retrieved at holding level.

4.1.3 Finance providers and flows

The finance (or capital) providers and estimated financial flows to cover investment costs from these providers to the recipients (DSOs and TSOs) for the year 2020 are shown in Figure 9. In reality lenders provide different types of debt to borrowers, including, for example, senior, junior, convertible, and green bonds.

Furthermore, equity is provided irregularly, and not necessarily on an annual basis. Equity provided to TenneT Germany by its owner, the Dutch Ministry of Finance, is not included in the figure as these are investments in infrastructure that lie outside of the national borders of the Netherlands. Equity for DSOs is provided by provinces and municipalities. Given the increasing investments of electricity DSOs, DSOs' demand for equity is also rising very significantly. Since provinces and municipalities have limited capabilities to provide such amounts of equity, and this trend is likely to continue, DSOs foresee financing issues. Recently, the Ministry of Finance announced to step in as equity provider, details are not yet known.

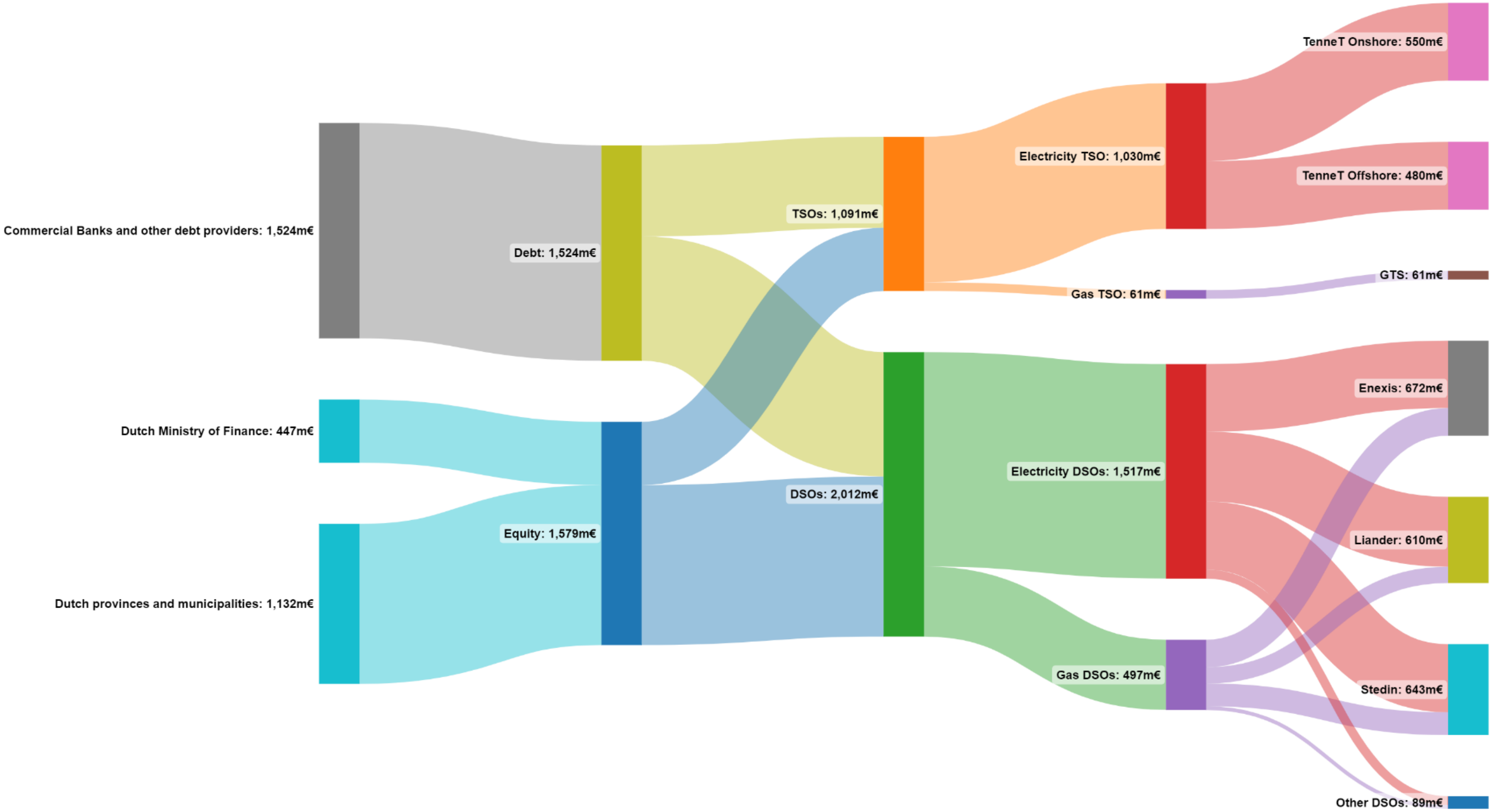

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Figure 9: Financial flow overview of the energy networks sector in the Netherlands in 2020

Figure 9 shows that approximately 49% (€1.5bn) of total financing of energy networks in the Netherlands in 2020 was sourced from commercial banks or other debt providers, and the remaining 51% (€1.6bn) was equity from national, regional and local public financing sources (the Dutch Ministry of Finance, and Provinces and Municipalities).

35% (€1.1bn) of total financing (€3.1bn) flowed to the TSOs of TenneT and GasUnie, and 65% (€2bn) to the DSOs, including Stedin, Liander and Enexis.

94% (€1.03bn) of the total financing for TSOs flowed to the electricity TSO TenneT, 53% (€550m) of which was for onshore network development and 47% (€480m) for offshore development. Only 6% (€61m) of total financing of energy networks flowed to the gas transmission system operator, Gas Transmission Services (GTS). 75% (€1.5bn) of total financing for DSOs flowed to electricity DSOs, and 25% to gas DSOs.

4.2 Power supply

This section presents the results of financial flows from sources of finance to power generation technologies in the Netherlands. These are preliminary results and some assumptions made rely on expert judgement of the researchers and interviewees, rather than a strong evidence-based. This reliance is mainly due to a combination of a lack of publicly available financial data for the power sector in the Netherlands, limited to no financial resources to acquire commercial data, and limited capacity restrictions to carry out more in depth research at this stage.

The two distinctive approaches in this study to calculating investment costs for different technologies over time, as introduced in section 3, are the overnight and annualised approaches. Figure 10 below shows the total annual investments between 2010 and 2020 in the power supply sector, assuming the CAPEX investment for projects takes place overnight, i.e. at the time the final investment decision is made. Taking this approach means that the total CAPEX investment in a project is accounted for in the same year that the final investment decision was made.

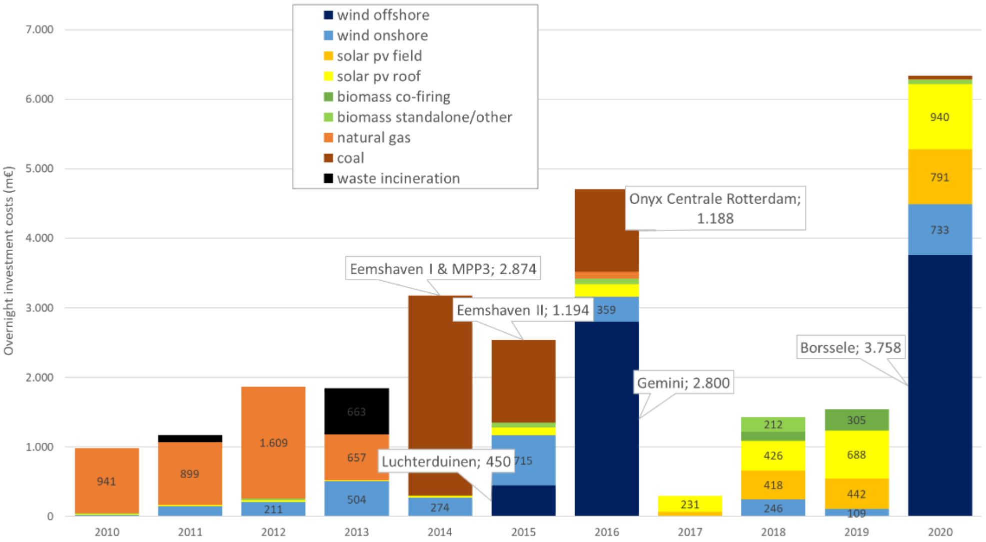

Figure 10: Overnight investment in the power supply sector in the Netherlands from 2010 to 2020.

Figure 10 shows that the large coal (Eeemshaven and Onyx) and offshore wind power plants (Luchterduinen, Gemini and Borssele) contribute large proportions of total CAPEX investments in the year that the investment decision takes place. For example, in 2016, the combined investment of the Onyx coal plant and Gemini offshore wind plant was almost €4bn which accounted for over 80% of total power plant CAPEX investment in that year. Allocating CAPEX investment on an overnight basis leads to high volatility in total investment across years, as can be seen in Figure 10. Furthermore, taking this approach means that no CAPEX investment in coal or natural gas power plants is assumed to take place after the year 2016. In reality CAPEX investment needs to be financed, and that finance to be serviced or paid back over a time period that is specified in the agreement between the financier and the project developer.

Figure 10 shows a clear shift from investment in fossil fuel based generation to renewable generation assets since 2015-2016. The expansion of natural gas and coal-fired power generation assets has experienced a boom-and-bust cycle in the Netherlands over recent decades, and between 2010 and 2016 a large majority of investment in new power generation was in fossil fuel assets. Since 2015-2016, investment in renewable power generation has taken over, and there has been little to no overnight CAPEX investment in fossil fuel generation. Strong policy has played a role here, with the Energy Agreement ('Energieakkoord') made in 2013 and the Climate Agreement ('Klimaatakkoord') being concluded in 2019.

Figure 11 shows the total annual investments between 2010 and 2020 in the power supply sector on an annualised basis over the average lifetime of projects i.e. the total investment in a project is distributed linearly over the average lifetime of a project in a specific technology group.

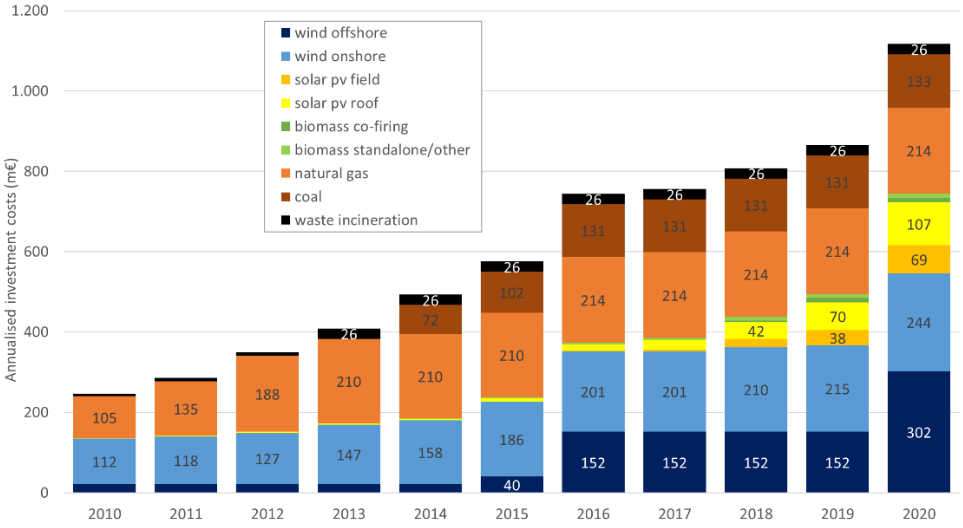

Figure 11: Annualised investment costs in the power supply sector in the Netherlands.

In this study, investments made in power generation assets before the year 2000 are not included. Accounting for investments made before the year 2000 would substantially increase the annual investment amounts for conventional generation technologies such as natural gas and coal when applying the annualised approach. The Netherlands invested heavily into these technologies before the year 2000 - almost 13GW installed capacity in the year 2000 in gas and about 4GW in coal - and the average lifetime of projects for these technologies is long - 30 years for natural gas and 40 years for coal. The annualised results in Figure 11 therefore show lower investment amounts between the years 2010 and 2020 in fossil fuel generation assets than have been made in reality.

There are significantly different annual investment levels across all power generation technologies depending on the approach taken to when to account for the investments made. Applying an overnight approach results in approximately €1bn of investment in 2010, increasing to more than €6bn in 2020. The investment levels when applying an annualised approach are substantially lower, at approximately €250m of total investment in 2010 to €1.1bn in 2020.

There is less volatility in the total annual investment levels across years by taking an annualised approach. This can be seen clearly in Figures 13 and 14 below, which show the percentage share of renewable versus fossil fuel (including the waste technology group) investments when taking an overnight and an annualised approach, respectively.

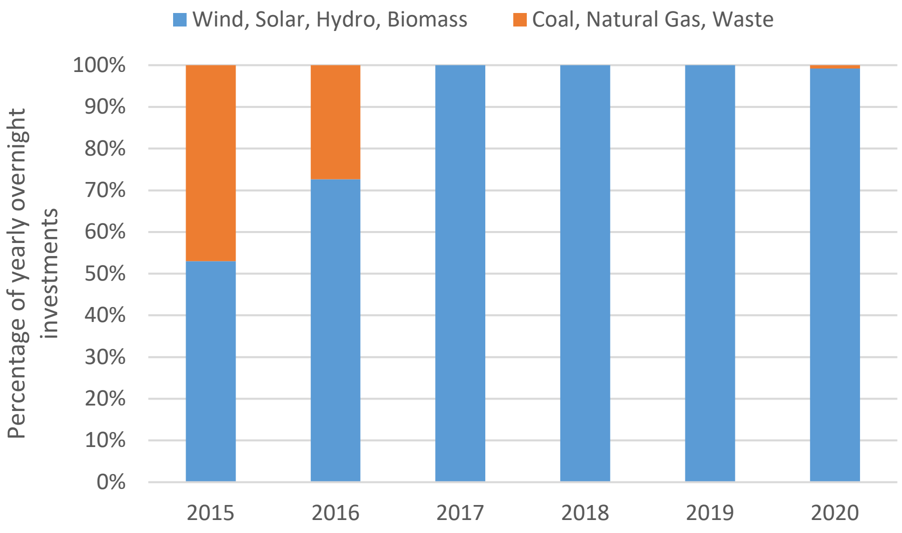

Figure 12: Percentage of annual investment in fossil fuel versus renewable energy generation using the overnight approach

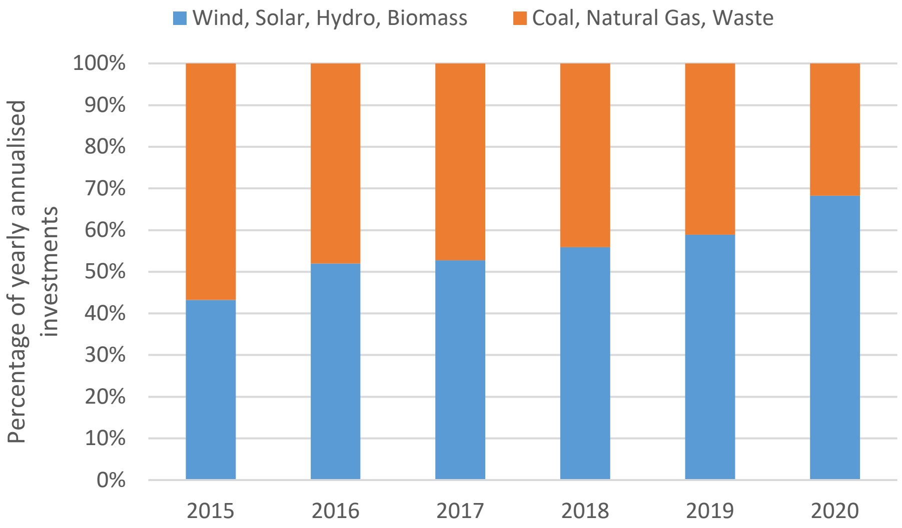

Figure 13: Percentage of annual investment in fossil fuel versus renewable energy generation using the annualised approach

Figure 14 below provides an overview of the financial flows in the power sector in 2020 using an annualised approach to calculating total annual investment. The amount of *direct* public financing of CAPEX investment in the power sector in the Netherlands is negligible, and thus only private investments have been tracked.

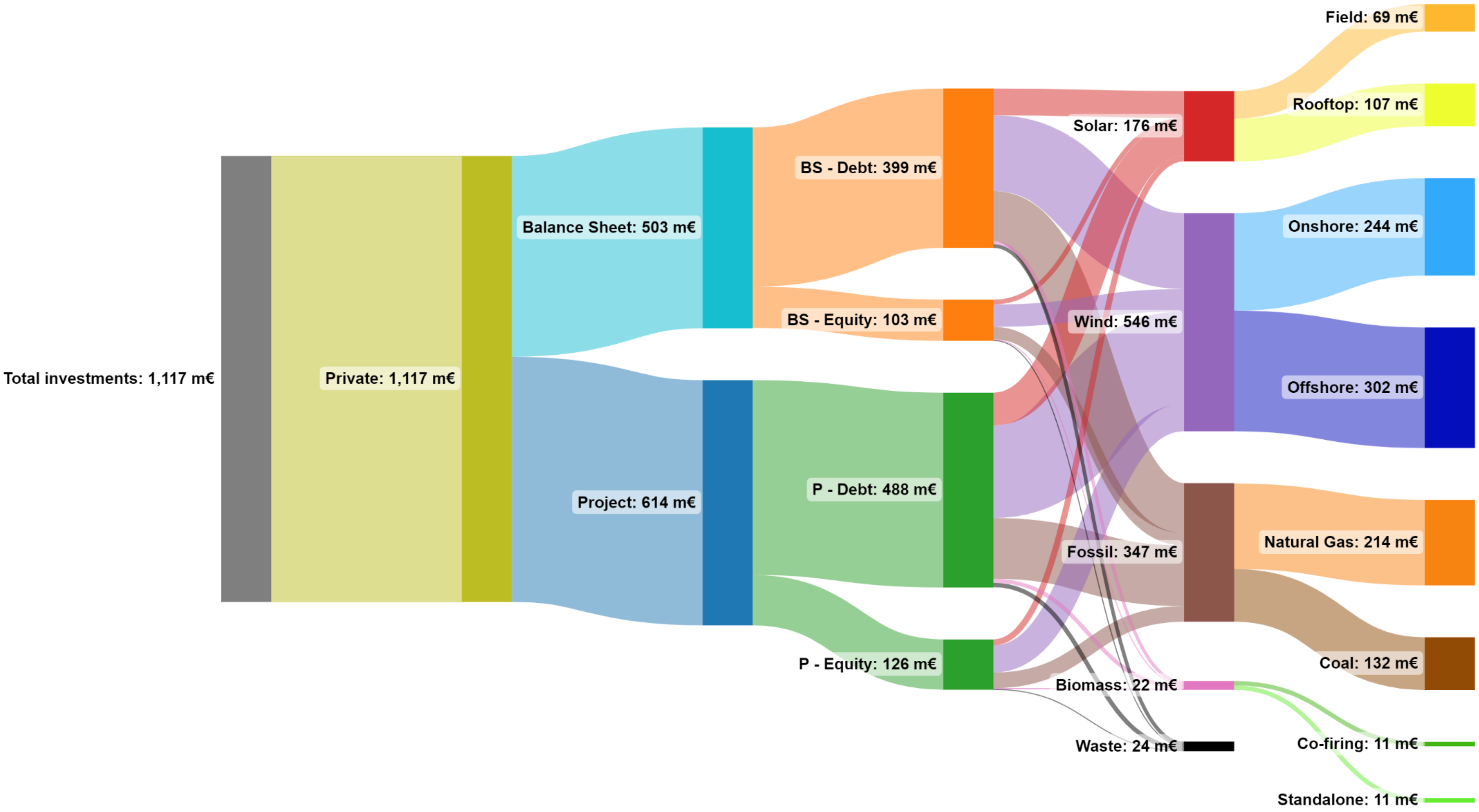

Figure 14: Financial flow overview of investments in the Netherlands in the energy supply sector in 2020.

Figure 14 shows that there was a slight preference for power generation assets to be financed on a project financing basis: approximately 55% (€614m) of total private sector financing in the power sector in the Netherlands was financed by project finance, and the remaining 45% (€503m) from balance sheets.

Debt financing accounted for 79% (€887m) of total financing in 2020, and 21% (€229m) via sources of equity. The debt to equity division was roughly the same (79% debt and 21% equity) for both project and balance sheet financing, respectively.

Fossil fuel generation assets accounted for 31% (€347m) of the total financial flows in 2020, with 61% (€214m) of that amount going to natural gas-fired and 39% (€132m) to coal-fired power plants. The renewable energy generation assets of wind (onshore and offshore) and solar PV (field and rooftop) accounted for 65% (€722m) of total financing.

5 Discussion

The main limitation of this study is the lack of a strong evidence base upon which the preliminary results have been developed. Publicly available financial data is limited, in particular financial data from private sector institutions which is often proprietary. For the power sector, identifying and estimating the amount of finance flowing from private sources to different power generation technologies was a significant challenge, and thus a breakdown of estimated financial flows from different sources of private finance is not presented. Commercial data providers are available, for example BNEF, but they are costly, and the financial resources were not available to acquire this data. Furthermore, there is no certainty provided by various commercial providers that were approached that the data is of suitable quality and granularity for quantifying financial flows at the national level in the Netherlands. For example, BNEF is a common source of data in developing landscapes of climate and energy system finance, but these are often developed at aggregated levels (regional e.g. European, and global), and not at the national level.

The study estimates historical financial flows over the past decade. It is useful for policymakers to look back, identify investment and financing trends, and conduct further analysis into the efficiency and effectiveness of, for example, policy to mobilise private sector investment. Projections of future financial flows, the potential sources of finance, and where these flows need to go to meet policy objectives and targets, is even more relevant for policymakers. Tracking financial flows in the energy system on an ongoing, periodic basis, such as annually, would provide a basis from which to make such projections and better support policy decision-making.

The estimated financial flows in the two sectors analysed in this study cover both fossil-fuel and low carbon energy sources. Financial flows for the power sector cover investment in coal-fired and natural gas-fired power plants, and for energy networks the investments in natural gas infrastructure and the transportation of electric power generated from non-renewable sources. It was not possible to distinguish between investments in renewable and non-renewable sources of energy in the energy networks sector, which means that estimating only the financial flows that contribute to the energy transition was not possible.

The study only includes CAPEX when estimating financial flows on an annualised basis, and not OPEX or the costs of capital. This means that estimates of financial flows to fossil fuel based power generation are conservative because they do not include the financing of the fuel inputs of coal and natural gas. Furthermore, financial flows to renewable power generation technologies do not include the billions of euros of public spending that is spent on subsidising the operating cash flows of renewable power generation projects, and thus these financial flow estimates are also conservative.

The preliminary results in section 4 are captured in Sankey diagrams. Sankey diagrams are an effective tool to visualise multiple data points in one overview. For example, the Sankey diagram showing the results of the Power sector analysis compiles a table with 10 columns and 12 rows. A drawback of using Sankey diagrams as a visualisation tool is that the results can sometimes be difficult to interpret without referring to the underlying data. Furthermore it is only possible to show one year of data and not multiple years in one Sankey diagram.

6 Conclusion and next steps

This paper describes the research that TNO has conducted in 2022 to develop a methodology to start to track financial flows in the energy system of the Netherlands. The state-of-the-art literature and methodologies to track financial flows at global, regional and national levels have been reviewed, and interviews conducted with representatives of the organisations that have undertaken this work, including the IEA, IRENA, CPI, IKEM, and I4CE. TNO has also discussed the research with key stakeholders in the Netherlands who are interested in further studies in this domain, such as the National Statistical Office (CBS), Top Sector Energy, InvestNL, and the Ministry of Economic Affairs and Climate Policy (EZK). There is a need to improve the evidence base on the costs and financing of the energy transition, for both the current situation and future projections of investments and financing needed to achieve energy transition and climate goals. A stronger evidence base on costs and financing can support decision-making both for policymakers and private financiers about the energy transition, both strategically and tactically.

This study is a first attempt at developing and applying a methodology to estimate financing flows and generate preliminary results for the power sector and energy networks. Further work can be done to strengthen the evidence base upon which the methodology has been developed, and to improve the results generated. Several assumptions can be further validated through, for example, collecting additional data and additional expert/stakeholder interviews. The power sector analysis could be extended to estimate the financial flows from different sources of finance, and to show to which recipients the finances are flowing to e.g. residential, commercial, public actors. The study can also be extended to cover other sectors of the energy system, such as the built environment, industry and transport.

The main challenge to building a methodology to quantify, and consistently and continuously track, energy system financial flows the current lack of transparency of financial information. Private companies and institutions often keep this data for proprietary use only. To conduct a study based on strong evidence, access to such data is crucial. One way of improving transparency is to implement regulation that forces private parties to disclose data and information on financial investments made in the energy system, such has been the case in France. This has helped I4CE to gather data to develop their climate finance landscape and continue the work over the past 10 years.

This study analyses historical financial flows in the energy system. The financing needs of different energy transition scenarios going forward is more relevant for policymakers and financiers. A better understanding of these needs is essential for making informed decisions about policies that can stimulate scaling and acceleration of private investment and other public financing decisions. It is also essential for financiers to make informed investment and lending decisions in the energy transition so that they can mitigate and manage risk, while also generating the required returns.

As next steps, stakeholder consultation workshops are planned for 2023 to review the current methodology and preliminary results generated for energy networks and the power sector, and to gather input for further development (including for other sectors). The methodology and results or these two sectors will be refined after these workshops. Funding has been secured to develop a similar methodology for the built environment sector. The development phase will begin in March 2023, and results are expected to be available in early 2024.

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