Transitions Pathways and Risk Analysis for Climate Change Mitigation and Adaptation Strategies

D3.2 Context of 15 case studies:

The Netherlands: Solar PV & Livestock sector

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1 COUNTRY CASE STUDIES OF THE HUMAN INNOVATION SYSTEM (HIS): THE ENABLING ENVIRONMENT FOR SUSTAINABILITY

In 2002, the Netherlands ratified the Kyoto protocol as a Party with a quantified emission reduction commitment. In order to comply with this commitment, the Netherlands was among the first countries to invest in emission reduction projects abroad to offset domestic emissions. For that, it used Kyoto Protocol mechanisms: Joint Implementation and the Clean Development Mechanism. After the end of the first commitment period in 2012, the use of these mechanisms for compliance with international climate commitments has mostly ended. Nowadays, the focus is mainly on domestic mitigation actions, as part of implementation of EU climate and energy directives. For example, in 2015, the Netherlands together with the other 27 EU Member States communicated one single INDC (Intended Nationally Determined Contributions) to the UNFCCC Secretariat with the binding target of at least 40% domestic reduction of greenhouse gas emissions by 2030 compared to 1990 levels (EU, 2015). This target must be achieved jointly; hence no individual targets are set for the Member States.

The Netherlands, as part of the EU delegation, has signed on the Paris Agreement (The Paris Agreement, 2016), and is one of the partners of the Global Alliance on Climate Smart Agriculture (GACSA, 2016). As a member of the EU, the Netherlands is legally bound by climate change targets including energy efficiency and renewable energy targets. On top of that, the Dutch government has to comply with all kinds of EU legislation/directives in the field of agriculture, fertilisers, waste, water, etc. Nevertheless, the Netherlands is lagging behind on the implementation of renewable energy technologies, therefore there is an urgent need to accelerate the implementation of such technologies. One of the options to intensify the implementation of renewables is the rapid solar PV expansion in the Dutch electricity sector, considering the large potential of the available building rooftops and suitable lands.

Large-scale solar establishments are scarce in the Netherlands and in a densely populated country such as this, the available land surface area is already intensively used for different purposes (e.g. housing, nature and agriculture, and industry), which can be a barrier to a rapid expansion of large-scale solar PV.

The Dutch government—in general—has the ambition to comply with the (environmental) targets agreed at the EU level, and uses a broad mix of policy instruments to achieve that (voluntary, subsidies, quota systems, etc.). In the area of climate change mitigation, the government typically aims to develop some kind of 'Effort Sharing', where each (sub-) sector, such as agriculture, gets a quantitative sectoral target. In the case of agriculture, there are several (indicative; and often not formally binding) sectoral agreements (e.g. the target for non-CO_2 emissions in agriculture in 2020 is the most relevant in the area of climate change, and mainly concerns CH_4 and N_2O emissions).

Improving the sustainability of the livestock sector is one of the key challenges for the country. Within the EU, the Netherlands has one of the highest livestock densities. This brings along economic growth and jobs, but also is associated with a range of negative environmental impacts, including greenhouse gas emissions, but also air and water polluting emissions. For example, the Netherlands has a significant surplus of soil nutrients embedded in animal manure, which is a by-product from the livestock sector; this manure surplus is already in place for several decades. Moreover, the emissions of air pollutants, mainly ammonia (NH_3), are another result of the livestock sector. The Netherlands already records several years where the national emission ceiling on NH_3 emissions has not been met.

Given the diverse nature of the environmental impacts of the Dutch livestock sector, it would be strongly preferable that any low-carbon transition pathway for this sector aimed to select those technologies and practices that address multiple targets at the same time.

A key objective of this case study would be to evaluate the social, economic and environmental impacts of the alternative future scenarios/transition pathways in the energy sector and livestock sector, which enable the assessment of the effectiveness of possible policy mixes (with the help of existing models).

1.1 Research questions for the Dutch case studies

1.1.1 Solar PV (energy sector)

Overarching research question: What low-emission electricity generation options are available to reduce CO_2 emissions while considering the Dutch economic, political, social and environmental priorities?

1. **What are the economic, social and environmental priorities of the Netherlands towards supporting a low-emission transition, including short- and long-term plans?**
   a. How can the Netherlands improve its use of renewable energy resources, and in particular renewable electricity, to support sustainable growth and comply with renewable energy goals of the EU?
   b. What is the current role of solar PV in the national plans and how and where can this be enlarged considering the answer to 1.a?
2. **What changes are required in the Netherlands to increase the share of solar PV in electricity production?**
   a. Which transition pathway is the most effective for reaching national goals: up-scaling the residential solar panel use (rooftops) or large-scale solar applications (non-residential areas)?
   b. Who are the key stakeholders (individuals, firms or institutions) influencing and/or driving the solar power sector in the NL?
   c. What are the interests and capabilities of actors involved in the solar PV market?
   d. Given the current context and plans, how rapidly would solar PV develop in the future?
   e. What is the role of public opinion and perception on the feasibility of residential and large-scale solar panel applications?

3. **What are the policy options for stimulating the Dutch solar electricity market via rooftop solar PV and/or solar parks?**
    a. What opportunities could these options bring about in terms of realising social, economic and environmental benefits?
    b. What are possible risks related to pursuing the extended solar PV pathway concerning knock on effects to other parts or sectors in the country, such as stability of a more decentralised energy system, solar as intermittent source and fiscal budget revenues (lower energy tax revenues)?
    c. What are possible risks concerning the successful implementation of the pathway, such as insufficient public acceptance, existing spatial planning which may insufficiently consider large-scale solar PV expansion and relatively high opportunity costs when using areas for solar parks?
    d. How likely are the risks under b) and c) to happen (i.e. indication of uncertainty) and what this implies for the need to mitigate these risks for realising both a socially, economically and environmentally beneficial pathway for the country and successful implementation of the pathway?
4. **What actions can be taken to mitigate the risks identified?**

Concerning knock-on (consequential) risks for the country, such as:

a. Impacts and implications (reliability, affordability) of small and large scale deployment of solar PVs.
b. Balancing issues on the electricity grid related to upscaling of solar energy.
c. Cost implications of small and large scale solar power generation for end users.
d. Fiscal budget implications of lower energy taxes when upscaling solar PV.

Concerning risks related to implementation of the pathway, such as:

e. Limited awareness of consumers about current technological improvements, cost and benefits of solar PVs.
f. Insufficient awareness of architects and construction companies of constructions for optimal use of solar PVs under Dutch climatic circumstances.
g. Insufficient awareness of spatial planners in urban areas of options for optimally using solar PV potentials.
h. Insufficient availability of flexibility options to deal with fluctuations in electricity supply due to increased solar PV and slow market adoption of these options.

1.1.2 Integrated Manure Management in the livestock sector (livestock and agriculture sector)

RQ1: How can the Netherlands optimise its strategy to improve the environmental and social performance of the livestock and agricultural sector, while contributing to energy and climate ambitions?

RQ1a: How can the livestock sector reduce GHG emissions and maintain employment levels, while remaining competitive in the food markets?

RQ1b: What are cost-effective options for the livestock sector to reduce CH_4 emissions?

RQ1c: How can the livestock sector establish cost-competitive manure-based biogas plants?

RQ2: What (policy) changes are required in the Netherlands to cost-effectively reduce the GHG emissions in the livestock sector, while increasing the share of renewable energy and maintaining/increasing employment?

RQ2a: Which transition pathways need to be considered next to current preferences?

RQ2b: What are the 'integrated' costs, benefits, risks and opportunities of the low-carbon transition pathways presented above (e.g. economic, social and environmental impacts)?[1]

RQ2c: What are the interests and capabilities of actors involved in the transition pathways and what are the external pressures that may influence (frustrate/foster) the further development of a transition pathway?

RQ3: Policy mix, risks and uncertainties

RQ3a: Which mix of policy instruments will best achieve the combined objectives in the most cost-efficient manner for the selected transition pathways?

RQ3b: What are the key uncertainties involved and in which dimensions, for each relevant transition pathway, and what are they dependent on?

RQ3c: What are the risks and opportunities of the policy mixes connected to the identified transition pathways and given the uncertainties?

RQ4. How can we prepare to deal with these risks and options, what policy mix would fit best within each individual transition pathway?

[1] For this question, I assume that the costs, benefits, risks and opportunities of the chosen transition pathway need to be compared to a reference or alternative scenario. Any reference scenario (even a doing nothing scenario) also entails certain costs, benefits, risks and opportunities.

1.2 Introduction to the general context

Currently, the Netherlands is faced with compliance challenges related to the EU Climate and Energy Package of 2009, with goals to be achieved by the year 2020 at the latest. The reduction commitment for 2020 (also known as the "20-20-20 targets") consists of 3 main objectives:

- a 20% reduction of the EU`s GHG emissions relative to the 1990 levels
- a 20% share of renewable energy in the EU`s energy consumption and
- a 20% improvement in the EU`s energy efficiency.

In the Netherlands, this has been translated to the following objectives (Ministry of Infrastructure and Environment, 2016):

- a binding target to reduce emissions in sectors not covered by the ETS by 16% (compared to 2005),
- a binding target of achieving a 14% renewable energy share, and
- a 1.5% of energy efficiency saving per year.

The use of renewable energy has risen to 5.8% of total energy consumption in 2015 which was only a 0.3% increase compared to the year before (CBS, 2016a). More than 90% of energy used in the Netherlands is still generated from traditional energy sources such as gas, coal and oil. For complying with the 14% renewable energy share target for 2020, it is thus important to accelerate the diffusion of renewable energy technologies in the country. At the same time, it is acknowledged that energy generated from renewable energy sources are characterised as intermittent, i.e. their supply can vary because of uncontrollable factors such as weather conditions. Therefore, renewable energy supply can be largely unpredictable. For these reasons, while the government plans to reduce the country`s dependence on fossil energy sources, these will likely remain important in the energy transition process because of their affordability and reliability.

The Netherlands has enough energy reserves to see it through the next five to ten years. To secure the energy supply after that period, the government has decided (as part the Dutch Energy Agreement of 2013, see below):

- to allocate more resources to saving energy;
- to tighten the requirements that apply to old, environmentally unfriendly coal-fired power stations; and
- to boost wind and solar energy, requiring at least 16% of all energy to be generated from renewable sources by 2023.

1.2.1 Policy overview

1.2.1.1 Energy Sector

In 2013, the government concluded the so-called Energy Agreement (in Dutch: Energieakkoord; (SER, 2013) for Sustainable Growth with industries, non-governmental and environmental organisations, trade unions and multiple other parties, which is considered an important step in the development of a low-emission economy. With respect to energy saving, parties have agreed that annually (average) energy end use should decrease by 1.5%. In terms of increased renewable energy, the transposed national targets indicated above have been set of 14% by 2020 and 16% renewable energy share by 2023.

The parties are all jointly responsible for the successful implementation of the agreement but each party is responsible for the implementation of its own actions. All parties agreed to appoint a standing committee (representing all parties, including the government) within the Social and Economic Council of the Netherlands (SER) to monitor the progress with implementation of the energy agreement and take amending measures when required to achieve the common targets. The committee is also responsible for encouraging partners to take actions and develop the post-2020 agenda.

Current predictions forecast that the 14% target for renewable energy (European target for the Netherlands in 2020) will not be met, while the 2023 target for 16% renewable energy established in the 2014 Energy Agreement is considered to remain feasible (ECN, 2016).

In 2016, the Dutch government published an Energy Report on the `Transition to sustainable energy` that focuses on options for further development and diffusion of low-emission energy in the country after the Energy Agreement, i.e., beyond 2023 and with a longer-term focus towards 2050 (Ministry of Economic Affairs, 2016a). To achieve this, the policy focus is intended to be on CO_2 emission reduction, maximising energy transition efforts and opportunities as well as integrating energy in the spatial planning policy.

Considering the solar PV sector, there are no official targets at the moment beyond 2020. The National Solar Power Action Plan for 2016, developed by DNV GL sets a goal of 4 GWp in 2020 (DNV GL, 2016) which corresponds to about 12 PJ of generated solar power (assuming 850 load hours). In addition, based on historical growth rates, expert assessments and various benchmarks, the Action Plan proposes two growth scenarios for the future, namely a low-growth scenario with a 70 GWp roof potential of the built environment (households and utility buildings), and a more ambitious one, with a 150 GWp potential that includes the impact of technology development and other potentials outside the built environment (i.e. large-scale projects), both by 2075.

1.2.1.2 Livestock and agriculture sector

A part of this case study focuses on low carbon transition pathways in the Dutch livestock sector. This, overall, requires a cleaner and more resource-efficient process of producing animal proteins for human consumption. The livestock sector is part of the agricultural sector, in relation to which the Netherlands has a long history in the area of environmental policy making. Already before the establishment of the European Economic Community in 1957, there were specific national policies in place to reduce/or limit the emissions of certain environmental pollutants (e.g. emissions to soil, air, and water). Also, one of the first EU policy initiatives was the establishment of the Common Agricultural Policy (CAP). Even today, the CAP is one of EU's most comprehensive policy frameworks that heavily affects the way in which agriculture develops within the various EU Member States. The CAP was established in 1962.

As an EU Member State as well as an economy with an agricultural tradition and sizeable agro-industry, the Netherlands has set itself a wide range of environmental targets and ambitions. For improving the environmental performance of the livestock sector in the Netherlands, there are several relevant EU-level policy frameworks. Table 1 provides an overview of these EU policy frameworks, all of which have been implemented in the Netherlands and deployed a broad set of (specific) rules, regulations and subsidies. These policy frameworks are subject to changes and updates as the policy discussions and agreements progress (e.g. new international climate agreement after COP-21 in Paris).

Table 1: A selection of EU-level policy frameworks with relevance to the livestock sector

Environmental policy theme	Key EU Policy framework	General aim	Policy history	Relevance for livestock sector
Water quality	EU Nitrates Directive, 1991	Aims to protect water quality across Europe, by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices.	EU-level policy making on water quality already commenced in the early 80s.	Sets limits on the use of nitrogen and phosphate (derived) from animal manure on land.
Air quality	EU Air Quality Framework Directive (and following 'daughter directives'), 1996	Describes the basic principles as to how air quality should be assessed and managed in Member States. It lists the pollutants for which air quality standards and objectives will be developed and specified in legislation.	EU-level policy making on air quality already commenced in the early 80s.	Sets limits on the emissions of air pollutants like ammonia.
Renewable energy	EU Renewable Energy Directive, 2009	Promotes the production and use of energy from renewable sources.	EU-level policy making on renewable energy already started in the beginning of the 00s.	Sets targets on the desired minimum level of renewable energy production/consumption, and hence impacts on the viability of the production of biogas from animal manure.
Climate change	EU Energy and Climate Actions	Aims to reduce the impact of the EU's economy on climate change by establishing binding (national) targets for energy savings, renewable energy consumption as well as greenhouse gas emission reductions.	EU ratifies Kyoto Protocol on behalf of all EU Member States in 2002. First phase of EU Emissions Trading Scheme commences in 2005. Effort Sharing Decision for non-ETS sectors in 2009.	Sets limits on the emissions of greenhouse gases (e.g. CH_4, CO_2 and N_2O) to atmosphere.

Source: (compiled by authors)

It is interesting to note that the policy frameworks regarding (renewable) energy and climate change are relatively new, and really have started to develop after 2002, when the EU ratified the Kyoto Protocol on behalf of all EU Member States. The 'older' environmental policy frameworks regarding the quality of air and water were already developed in the early 80s. All of the aforementioned policy frameworks have resulted in a set of binding targets for the Netherlands.

Table 2 shows a set of key environmental targets for the Netherlands that (partially) apply to the agricultural sector in general and the livestock sector in particular. The target for renewable energy relates to the production of biogas from animal manure, while the climate and air quality targets can be linked to CH_4, N_2O and NH_3 emissions from the storage and use of animal manure. The EU's Clean Air Policy Package was recently adopted in 2016 and included national emission ceilings for at least five key air pollutants, namely PM, SO_2, NOx, VOCs and NH_3. The initial proposal, however, also included a national emissions target for methane (CH_4) emissions (EC, 2013a).

The targets regarding phosphate (and nitrogen) excretion are linked to a key requirement of the Dutch derogation of the Nitrates Directive (EC, The Nitrates Directive, 2016c). This derogation allows higher levels of N (nitrogen) and P (phosphates) from animal manure to be used on arable land in the Netherlands. This derogation was granted under the condition that the total national excretion level of phosphates (in animal manure) would not exceed a certain threshold. Current and historical emissions of the major pollutants for the agricultural sector are listed in Table 2.

Table 2: An overview of major emissions in the agricultural sector

Pollutant*	Unit	1990		2005		2010		2014		2015	
CH_4	Ton CO_2-eq.	15	45%	12	60%	12	60%	13	68%	13	68%
N_20	Ton CO_2-eq.	10	56%	7	50%	6	75%	6	75%	6	75%
CO_2	Ton CO_2-eq.	8	4,9%	7	3,9%	10	5,5%	7	4,4%	7	4,2%
NH_3	Kton	350	94%	137	86%	121	86%	114	85%	117	87%
PM_{10}	Kton	5	9%	5	14%	6	20%	6	23%	7	27%
N	Ton	691,1	-	478,8	-	489,7	-	486,7	-	497,5	-
P_2O_5	Ton	229,1	-	169,7	-	178,9	-	171,7	-	180,1	-

**Percentage values depict agricultural sector emissions as a share of national emissions of the pollutant (e.g. in 2015 the agricultural sector emitted 68% of all national CH_4 emissions, expressed in tCO_2-eq.)*

Source: (RIVM, 2016) and (CBS, 2016b)

Table 3 shows that, in order to meet the various (national/sectoral) environmental targets, considerable action is needed at the national level. The agricultural sector as a key source of emissions (e.g. greenhouse gases, ammonia, phosphates) also has to contribute to these actions. Particularly, the challenges in reducing phosphate (P_2O_5) excretion and increasing renewable energy production are high. However, also limiting the ammonia emissions in agriculture will become more problematic in the period up to 2030.

Table 3: An overview of key national/sectoral environmental targets relevant for the agricultural sector in the Netherlands

Target	Current (year)	2020	2030	Units	Source
Renewable energy	5,80% (2015)	14%	27% *	Gross final energy	EU Climate & Energy Framework (EC, 2016a)
Non-ETS	98,1 (2014)	111,6	-36%	Mt CO_2-eq.	(EC, 2016b)
Non CO_2-in agriculture	19 (2014)	16	N.A.	Mt CO_2-eq.	Agro Covenant (LNV, 2008)[2]
Air - methane (national)[@]	18,6 (2014)	N.A.	13,4	Mt CO2-eq.	Clean Air Policy Package (EC, COM(2013) 920 final, 2013a)
Air - ammonia (national)	134 (2014)	128	120	Kt	Clean Air Policy Package (EC, COM(2013) 920 final, 2013a)
Phosphates (national)	176,3 (2015)	172,9	N.A.	Mln. kg	Nitrates Directive (EC, 2016c)
Phosphates (dairy sector)	86,1 (2014)	84,9	N.A.	Mln. kg	Sector plan Livestock (LTO, 2013)

**At the EU level. National targets are not foreseen.*

@ The initial proposal for a new air quality directive included a national target for CH_4 emissions. However, just before the directive was formally adopted, this particular national emission target was deleted from the framework.

Data sources: (RIVM, 2016), (CBS, 2016c) and various EU Directives and sector covenants for quantitative targets 2020/2030 (as indicated in the table)

Current market and policy developments show that often only ‘partial’ (mitigation) solutions are implemented that—for example—only address a single environmental target, which could even negatively affect the achievement of another environmental target. More integrated solutions (i.e. robust transition pathways) are needed to simultaneously address multiple social and environmental targets.

[2] The ‘Agro-Covenant’ is a sectoral covenant (public-private partnership) that aims to enhance the production of renewable energy and reduce the GHG emissions of the Dutch agricultural sector.

1.2.2 Natural resources and environmental priorities

1.2.2.1 Energy sector

Primary production of energy[3]

For the future, the Netherlands government aims at a balanced mix of energy sources, reducing the country's dependence on any single source while keeping energy bills for consumers and businesses low. With that, the present dominance of natural gas and crude oil and petroleum (76.8% of total primary energy supply) could be softened with a larger share of renewables. The current energy mix of the Netherlands is shown in Table 4. The Table shows that the Netherlands produced more natural gas relative to its own domestic consumption, and hence (still) is an exporting country. However, with regards to oil and coal, the Netherlands has very limited domestic resources. The renewable energy category also includes bioenergy. Although all bioenergy is produced domestically, not all bioenergy subcategories make use of indigenous biomass resources. For a few bioenergy subcategories, also a certain share of biomass is imported from abroad, as is the case with the co-firing of wood-pellets.

Table 4: Total primary energy supply (total and indigenous) in the Netherlands in 2015 (based on provisional data of CBS) in PJ

	Total energy commodities	Indigenous production	Import dependence
Total primary energy supply	2992 (100%)	1923 (100%)	36%
Total coal and coal products	445 (14,9%)	- (0%)	100%
Total crude and petroleum	1102 (36,8%)	94 (4,9%)	91,5%
Natural gas	1199 (40%)	1621 (84,3%)	-35%
Renewable energy	134 (4,5%)	133 (6,9%)	1%
Nuclear energy	39 (1,7%)	39 (2,0%	0%
Other sources	42 (1,8%)	36 (1,9%)	15%
Electricity	31 (1,3%)	- (0%)	-

Source: (CBS, 2016d)

The Netherlands has a long history of using natural gas as it is a domestically available energy source discovered in the 1950's. Since then virtually all households have been connected to the natural gas grid and several power plants were built that run on natural gas. On one hand, this has put the Netherlands in a comfortable position of being the largest natural gas producer in the EU and becoming a net exporter of natural gas. The overall sustainability performance of domestic natural gas is also relatively good (in terms of emissions of greenhouse gases and other pollutants), compared to other fossil fuels. On the other hand, large-scale availability of natural gas has

[3] Primary production of energy is any extraction of energy products in a useable form from natural sources. This occurs either when natural sources are exploited (for example, in coal mines, crude oil fields, hydro power plants) or in the fabrication of biofuels.
(http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Primary_energy_production)

reduced the need in the country to accelerate development and diffusion of renewable energy options. This has made a low-emission energy transition much more complex and challenging for the Netherlands relative to countries with high import dependencies.

Nevertheless, the situation in the Netherlands is gradually changing as annual gas production has already peaked on the Dutch continental shelf. More recently, the increased frequency and intensity of earthquakes in the main onshore gas production region in the Northern part of the country has considerably changed the public opinion on natural gas from a national 'jewel' to a problematic energy source with impacts on peoples' well-being. The earthquakes are a direct result of gas production[4] and measures have already been taken to limit the production from this region, in an attempt to minimise the stress on the geological formations, and reduce or stabilise the intensities of the earthquakes. Since most of the above-ground infrastructure was not built and developed to sustain earthquakes (i.e. the country is not located near any significant fault lines) there already is significant damage sustained. Moreover, although the domestic gas reserves are still significant, by 2025-2030 and onwards[5] importing natural gas will increasingly be needed to meet domestic energy demand. For both reasons, earthquakes and increasing gas imports, there will be stronger incentives to speed up the energy transition.

Besides natural gas, there are other naturally available resources such as crude oil from North-Sea drillings, peat, limestone, salt, sand and gravel. The production of oil however covers only a fraction of the domestic and industrial needs, so that a large amount of oil needs to be imported for refining. At the same time, a large amount of refined oil, processed in the Netherlands based on crude oil, is exported. In order to mitigate the risks related to importing oil from politically unstable regions, the Netherlands government holds large strategic reserves.

Most Dutch power plants run either on natural gas or coal. Some of the power plants run on biomass and some of the coal power plants also use wood pellets for co-firing. Coal, however, is not available domestically, hence the Netherlands must import several million tons of coal to meet the demand of such industrial installations. Coal is cheap but it is also the dirtiest energy source due to its large carbon content and other harmful substance emissions that have a largely negative impact on the environment. Nevertheless, the production of electricity by coal plants is still cheaper than by gas-fired plants even after the reintroduction of a carbon tax, so that a substantial shift from coal towards gas plants has not taken place. The government did not plan to increase this tax, but rather to conduct a tax reform, introducing flexible tax rates depending on the efficiency of the coal plants (Caymaz, 2013). The tax reform however was not realised. Instead, as part of the Energy Agreement, a coal tax exemption was reintroduced in 2016 for electricity

[4] Specific onshore production areas (e.g. Groningen area in the Northern part of the Netherlands,) are more affected than others with a maximum recorded earthquake of 3.6. Richter scale and about 100 shocks (large and small) registered per annum. Several studies/reports suggest that later even > 3.9 Richter scale earthquakes can be expected.

[5] "The Netherlands is a net exporter of natural gas and, based on the current levels of domestic gas consumption, will be able to remain self-sufficient for at least another decade to 2025. If the upside scenario materialises, this might be stretched to 2030." "According to the 'business as usual' scenario, the Netherlands will be able to remain self-sufficient for at least another decade. In the 'upside' scenario, however, we could still produce about half of the country's forecast consumption [of about 20 bcm] in 2040." (EBN, 2014)

producers. In return, coal power plants built in the 1980s must be shut down to mitigate GHG as well as NO_x, SO_x and PM emissions.[6] A study of the Authority and Consumers and Markets, however, shows that the environmental benefits of closing down coal plants may not outweigh the additional economic costs of higher energy prices (which have to be paid by the consumers in the form of increased energy tax) (ACM, 2013).

The Netherlands has only one nuclear power plant (in Borssele) that generates approximately 4% of the total electricity. In 1994, following a discussion on nuclear waste management, the Dutch Parliament voted to phase out nuclear energy from the national portfolio by 2003, but this was postponed by a next government to 2013 and later it was even decided to maintain the operation of the plant till 2034 with including the possibility of expansion.

Renewable energy contributes only a fraction of the total energy supply in the Netherlands. The breakdown of the final renewable energy consumption in 2015 is shown in Table 5. Most (over two-third) of the Dutch renewable energy is produced from biomass, followed by wind and geothermal sources. Interestingly, due to limited domestic biomass resources, the country needs to import most of this biomass (e.g. wood pellets from North America).

Table 5: Breakdown of the final consumption of renewable energy in the Netherlands in 2015

Final consumption of renewable energy	In TJ	In %
Total	118,479	100%
Biomass	80,077	67.6
Wind energy	24,805	21
Geothermal	6096	5.1
Solar energy	5127	4.3
Aerothermal heat	2019	1.7
Hydro power	355	0.3

Source: (CBS, 2016e)

Technological lock-ins are an important factor to consider when assessing transition pathways. Table 6 shows that on the one hand, old power plants based on fossil fuels are about to reach their end-of-life cycle, but on the other hand, new power plants of the same kind (although more advanced) are being installed to replace them, which means that these plants might remain operational until 2040-2050 (based on their average technology life-time). This is in line with the long-term plan of the Dutch government to have an energy transition phase where fossil fuels

[6] In fact, 3 out of the 5 oldest plants (built in the 80`s) were already closed from the beginning of 2016 and the remaining 2 are planned to be shut down in 2017. There are 2 coal plants built in the `90s which might also be closed in a short period of time. On the other hand, there are 3 new coal plants that started operation in 2015.

remain dominant. However, it does not give a large incentive to adopt lower-emissions energy technologies.

Operational renewable energy technologies in the Netherlands are still at the beginning of their life-spans. Solar PV installation only recently started to grow while wind power projects started to gain momentum in 2005.

Table 6: Dutch energy sector overview: shares, efficiency rates, technology life cycles, lock-ins

Dutch Energy fuel mix (and technologies)	Share of the total	Electricity generation mix	Average technology life cycle (years) (A)	Age of 80% of the infrastructure (years)(B)	Technology Lock-in. A-B (Years left)	Efficiency (% of power generating plants)
Coal	15	27.8	35	New: 2 Old: 28	New: 33 Old: 7[7]	46 42
Hydro	0.01	0.1	75	20	55	70
Nuclear	1.3	4.0	50	42	8 (17)[8]	33
Gas	40	49.3	35	13[9]	22	58
Wind	0.95	5.6	20	7	13	50
Oil	36.8	0.3[10]	-	-	-	35
Solar PV[11]	0.2	0.8	25	2	23	15
Geothermal	0.23	-	30	0[12]	30	12
Biomass	3	4.8	22.5	7[13]	15.5	35
Other	2.51	7.3	-	-	-	-
Total	100	100	-	-	-	-

Source: (CBS, 2016d), (CBS, 2016e), (TenneT, 2016) and multiple websites of individual power plants and technologies (complied by the authors)

[7] The Energy Agreement states that 5 coal power plants built in the 80`s will be shut down starting from 2016. This includes those that also use biomass for co-firing.
[8] The nuclear power plant in Borssele will be open until 2033.
[9] There are more than 30 gas power plant in the Netherlands from which some are rather old, built between 1960 and 1980. However, older plants make up only for about 15% of the total production capacity. Since the profitability of gas power plants was declining in the last couple of years because of the availability of cheap coal, energy companies are considering to close down their gas power plants, starting with the older less efficient ones.
[10] Mostly used as fuel in back-up generators in large power plants.
[11] There are currently, no large-scale solar parks in the Netherlands. Solar PVs are only used by households and businesses to generate own electricity (the extra electricity is fed into the national electricity grid).
[12] Currently, electricity production from geothermal sources is non-existent. Geothermal sources are mostly used for heat generation in greenhouses.
[13] Co-firing biomass has a longer history than power plants running on 100% biomass. Coal plants started to co-fire biomass more extensively from 2003 when the government introduced the long-term subsidy called MEP to support the production of electricity from renewable sources. Therefore, the age of the infrastructure for this type of technology is about 13 years.

Since one of the focus of this case study is on electricity generation from solar energy, in the following two subsections we focus only on the Dutch electricity.

Gross electricity generation[14]

Similar to trend for the Dutch energy mix, in 2015, most of the electricity is produced from fossil fuels (81%), while around 12% of electricity is generated from renewable sources (see Table 7).

Table 7: Gross production of electricity from various energy commodities in the Netherlands in 2015

Energy commodities	In TJ	In %
Total energy commodities	396,011	100
Total fossil fuels	320,614	81
Natural gas	183,571	42
Hard coal	139,911	35.3
Fuel oil	277	0.1
Other	14,239	3.6
Total renewable energy	49,169	12.4
Wind energy	26,960	6.8
Biomass	17,881	4.5
Nuclear power	14,681	3.7
Solar energy	3989	1.0
Hydro power	335	0.1
Other	11,547	2.9

Source: (CBS, 2016f)

The production of electricity occurs both centralised and decentralised. The historical curve of electricity production, shown in Figure 1, illustrates how the ratio between central and decentral electricity production has changed since the 1940s.

[14] Net electricity generation or net electricity production is equal to gross electricity generation minus the consumption of power stations' auxiliary services (http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Net_electricity_generation).

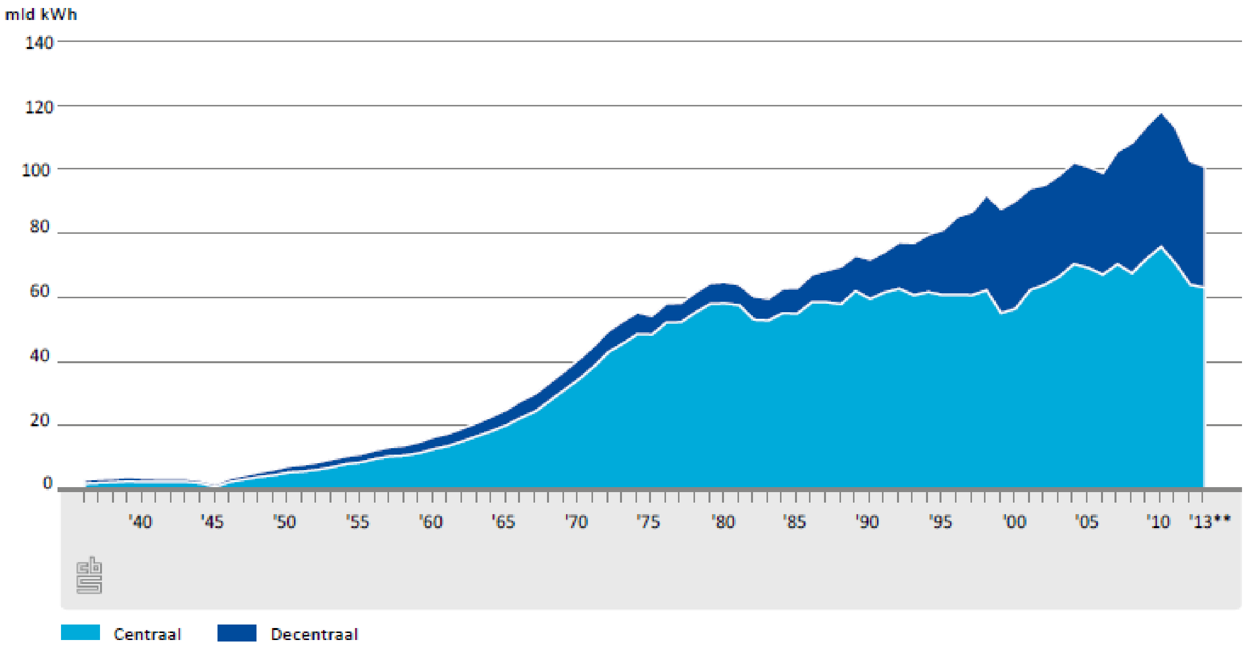

Figure 1: Historical share of centralised and decentralised electricity production in the Netherlands

Source: (CBS, 2015)

After the Second World War, electricity production sharply increased until the 1980s, when it decreased for a short while, before growth accelerated again in the 1990s. Until the 1980s, the share of decentralised electricity production was very small, but after 1985 it started to become increasingly important. Presently, decentralised electricity technologies produce about 38% of total electricity production, which could be further increased by adapting more wind and solar installations. For example, the potential of solar energy is much larger than current utilisation. This will be discussed in section 2.3.

Energy use by end-user group

Table 8 below shows the final use of electricity per sector in 2014: 80% of the electricity is used by businesses and (semi-)governmental organisations and 20% by households.

Table 8: Final use of electricity per sectors in the Netherlands in 2014

Final use of electricity by sectors	In %
Total	100%
Agriculture, forestry and fisheries	4.3
Industry	23.6
Mining of minerals	2.3
Horeca	2.6
Energy supply	1.1
Water utilities and waste management	1.4
Construction	0.7
Trade	7.4
Transport	4.1
Households	19.4
Other (education, communication, services etc.)	33.1

Source: (CBS, 2014)

As shown in Figure 2 below, overall electricity consumption by all households has slightly grown over the past twenty years, while business and public organisations have increased their electricity consumption by around 20%.

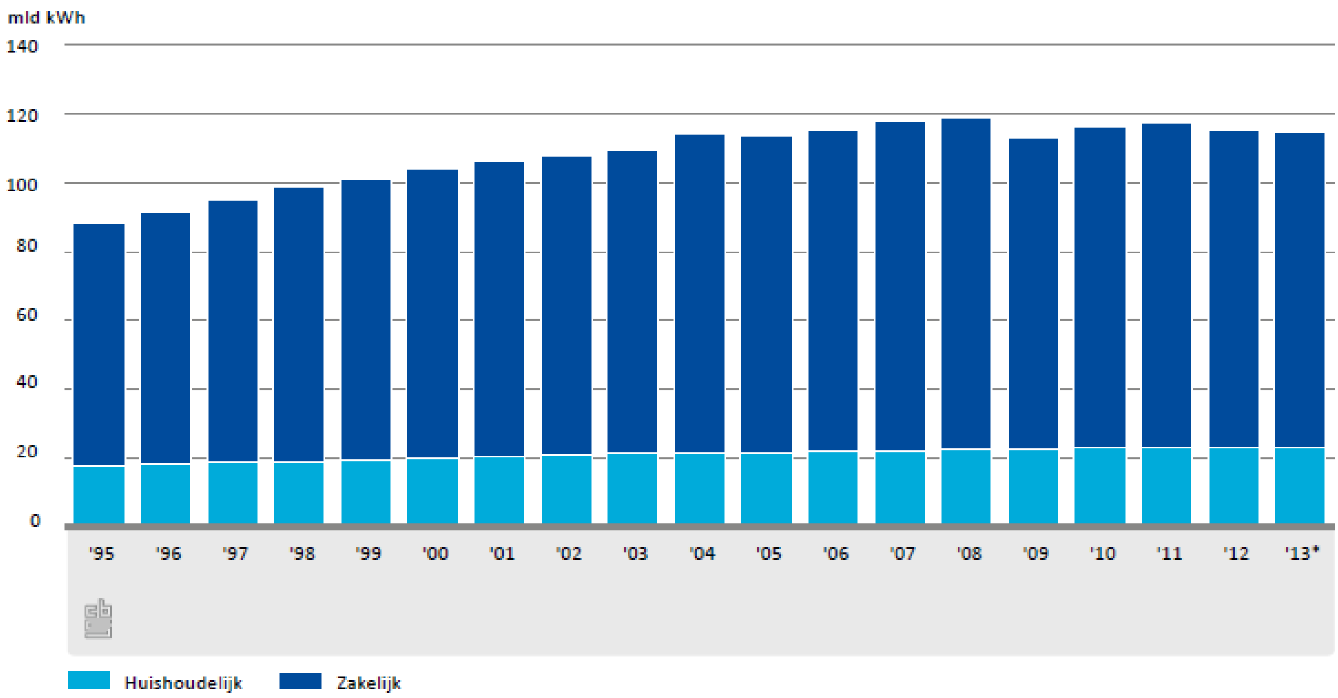

Figure 2: Historical electricity use of households and businesses in the Netherlands in billion kWh (light blue colour is associated with households while the darker blue colour corresponds to businesses)

Source: (CBS, 2015)

*Note: the light and dark blue colours represent the electricity (in billion kWh) consumption of households and industry, respectively

The average electricity use per household is about 3100 kWh since 2006 while in the previous years it amounted to about 2800 kWh. This increase is due to the increased use of household appliances (e.g. freezer, tumble dryer and dishwasher) and computers.

By comparison, when the total energy consumption is taken into consideration, the major energy end-users differ from those of the electricity sector. Industry continues to be the largest energy end-user with 60% of the share while the power sector makes up the second largest with around 15% and agriculture, forestry and fishing make up the next largest share of 7% in 2014 (CLO, 2016a).

Carbon emissions emitted by sector

In 2014, total GHG emissions in the Netherlands amounted to 158 million tons CO_2-equivalent. Carbon emissions per sectors are shown in

Table 9. Most of the emissions originate from the industry and energy sectors (60%) followed by the transport (21.5%) and built environment (14.1%).

Table 9: CO_2-emissions per sectors in the Netherlands in 2014

GHG emissions per sector	In million ton of CO_2-equivalent	In %
Total	158	100
Agriculture	7	4.4
Industry and energy	94.8	60
Transport	33.9	21.5
Built environment	22.3	14.1

Source: (CLO, 2016b)

Carbon emissions per capita

In 2014, the Dutch population amounted to 16,829,289 (CBS, 2016g) which means that the carbon emissions per capita are about 0.1 ton CO_2-equivalent.

The environmental priorities of the Dutch government, in terms of goals, have been already discussed in the introduction section of Chapter 1.2. In summary, while maintaining energy security is crucial, a gradual transition from fossil fuels to renewables needs to be accomplished as well to reach the 16 percent reduction in greenhouse gas emissions by 2023 (base year 2005). This can be achieved by using natural gas as back-up energy source, phase out of coal plants, increase the share of decentralised electricity systems. However, it was challenged by the public whether this percentage of emission reduction is sufficient enough. This will be discussed in more detail in section 1.2.4.

Considering renewable energy, the government has only short term plans with a particular focus on biomass and wind power. Domestic and imported[15] biomass is mostly used in waste incinerators to generate electricity. In addition, a large amount of wood pellets and chips are used by coal power plants for co-firing. The Energy Agreement set out that the promotion of biomass co-firing cannot exceed the limit of 25 PJ. Nevertheless, the stimulation of biomass co-firing is a powerful tool to reach the 14% renewable energy target by 2020. Therefore, co-firing of biomass has been

[15] Incineration capacity in the Netherlands is larger than domestically available biomass could satisfy therefore large amount is also imported from abroad.

included in the national renewable energy subsidy scheme as an eligible technology for financial support. This is only applicable for new power plants or those that were built in the 1990s.

As the general picture shows, solar energy was not one of the centrepieces of the Dutch government. One of the reasons was that in the years before, the technology to generate solar power (or heat) was rather costly. This has radically changed recently, as the cost of solar PVs has dropped significantly. At the moment, however, only part of the households and small businesses opted to equip their roofs with solar PVs. Large-scale solar establishments are currently non-existing for the same reason, but this is expected to change since the national feed-in subsidy scheme has been reorganised and support is more fairly distributed among the eligible categories.

1.2.2.2 Livestock and agriculture sector

There are different market or economic systems/sectors linked to the livestock sector, such as the energy system and the agricultural system. In terms of natural resources, the total number of animals (livestock), the excretion/production of animal manure, the availability and use of arable land, as well as the domestic availability of biomass resources for energy and non-energy applications are relevant.

Livestock

The Netherlands has a large livestock sector relative to its country size. The main animal categories in terms of animal numbers are swine/pig, chickens and cattle (Table 10). The country is a large producer and exporter of meat, dairy products and eggs. As a result, the livestock sector has a considerable contribution to the Dutch economy, in terms of income and employment. However, more livestock also implies that more animal manure is produced. Holding animals and storing and using animal manure comes with a series of negative social and environmental effects that need to be mitigated.

Table 10: Total number of animals per main animal category for various years in the Netherlands

	2000	2005	2010	2013	2014	2015
Cattle (total)	4 068 709	3 796 778	3 975 194	3 999 221	4 068 331	4 133 854
Sheep (total)	1 304 567	1 360 509	1 129 500	1 033 566	958 602	946 179
Goats (total)	178 571	291 891	352 828	412 545	431 421	469 749
Horses & Pony's (total)	117 490	132 551	142 531	130 540	126 586	118 385
Swine (total)	13 117 814	11 311 558	12 254 972	12 212 303	1 238 120	12 602 888
Chickens (total)	104 014 665	92 914 176	101 247 711	97 719 294	103 038 539	106 762 945
Turkeys (total)	1543830	1 245 420	1 036 277	840 766	793 856	862 981
Slaughter ducks	958466	1 030 867	1 086 990	810 354	852 894	932 238
Other poultry (total)	296247	274 620	250 331	57 582	52 542	49 661
Rabbits (total)	392193	360 473	298 834	311 017	320 672	381 133
Fur-bearing animals (total)	589737	703 715	963 803	1 031 163	1 002 902	1 023 034

Source: (CBS, 2016h)

Animal manure

Animal manure is a 'by-product' of the livestock sector, and is produced in solid and liquid form. Each animal (sub-) category produces manure of a specific composition and thereby also has a different environmental impact. Liquid manure is by far the largest category in terms of volumes (about 96% of total manure production). The main animal categories that produce the most liquid manure are cattle (both dairy and non-dairy) and pigs. While pigs are most often kept in stable-systems year-round, a large portion of the cattle-stock spends a certain period of time in the meadow for grazing. Table 11 shows the historic production of animal manure in the Netherlands.

Table 11: Manure excretion per animal category for various years in the Netherlands

	1990	1995	2000	2005	2010	2013	2014	2015*
	Bln kg							
Total manure production	87,45	82,55	75,56	70,12	72,17	73,16	74,09	75,98
Liquid manure (slurry)	84,95	79,54	71,94	66,65	68,90	70,17	71,05	72,88
of which stemming from:								
Cattle (excreted in meadow)	20,69	19,33	16,92	13,81	8,37	6,88	7,00	7,56
Cattle (excreted in stable)	44,66	41,33	38,67	39,17	46,77	49,96	50,81	51,92
Pigs	16,36	16,15	14,13	11,85	11,84	11,47	11,42	11,65
Poultry	1,45	0,91	0,53	0,15	0,03	0,00	0,00	0,00
Other animal categories[1)]	1,79	1,83	1,70	1,68	1,90	1,86	1,81	1,76
Solid manure	2,50	3,01	3,62	3,47	3,27	2,98	3,04	3,10
of which stemming from:								
Cattle	0,84	1,02	1,14	1,06	0,81	0,59	0,58	0,56
Poultry	1,04	1,18	1,56	1,34	1,50	1,44	1,50	1,56
Other animal categories [2)]	0,60	0,81	0,92	1,08	0,97	0,95	0,96	0,97

Source: (CBS, 2016i)

The recent increase in manure production can largely be attributed to the increase in the number of dairy cattle in the Netherlands. This is a direct result of the abolition of the EU milk quota system on April 1, 2014. Anticipating the removal of the milk quotas, many Dutch (dairy) farmers invested in additional production capacity. Milk supply in the Netherlands (and thus also cattle manure) has increased substantially already since 2013 (see Table 12).

Table 12: Milk supply to dairy processing facilities in the Netherlands

Year	Milk supply (in 1000 kg)
2010	11 626 123
2011	11 641 718
2012	11 675 448
2013	12 212 690
2014	12 473 023
2015	13 325 976

Source: (CBS, 2016j)

The reason animal manure is labelled as a by-product is that it can be used as a resource for biogas production and/or as a soil fertiliser. The dominant use of untreated liquid animal manure in the Netherlands is the direct application to arable land for fertilisation purposes. A small percentage of the total manure production is treated in manure processing facilities and exported abroad. As a result of the large livestock sector, the Netherlands has a 'tradition' of oversupply of animal manure. The standard disposal method for animal manure is to use it on land as basic fertiliser. However, the Netherlands simply does not have enough arable land available to place all the manure on. Figure 3: Livestock densities in the EU in Livestock Units (LSU) per hectare of Utilised Agricultural Area (UAA) for 2013Figure 3 shows the livestock density for the EU-27 expressed in Livestock Units per hectare of Utilised Agricultural Land. The figure with data from 2013 clearly shows that the Netherlands has a relatively high livestock density.

In 2015 around 1.73 bln Kg (CBS, 2016c) of animal manure were used for the production of biogas in anaerobic digesters. This comprises roughly 2% of the total annual manure production in the Netherlands. This is a relatively small portion considering that the technical domestic biogas production potential for animal manure alone is estimated to be more than 50 PJ (BiomassPolicies, 2015).[16,17]

[16] "The energy potential that (theoretically) can be extracted from both liquid and solid animal manure in the Netherlands in 2020 is estimated at about 53 PJ."

[17] To put this in perspective, the current Dutch portfolio of all renewable energy sources combined (in 2015 deliver around 119 PJ of gross final energy (CBS, Hernieuwbare energie in Nederland, 2016c).

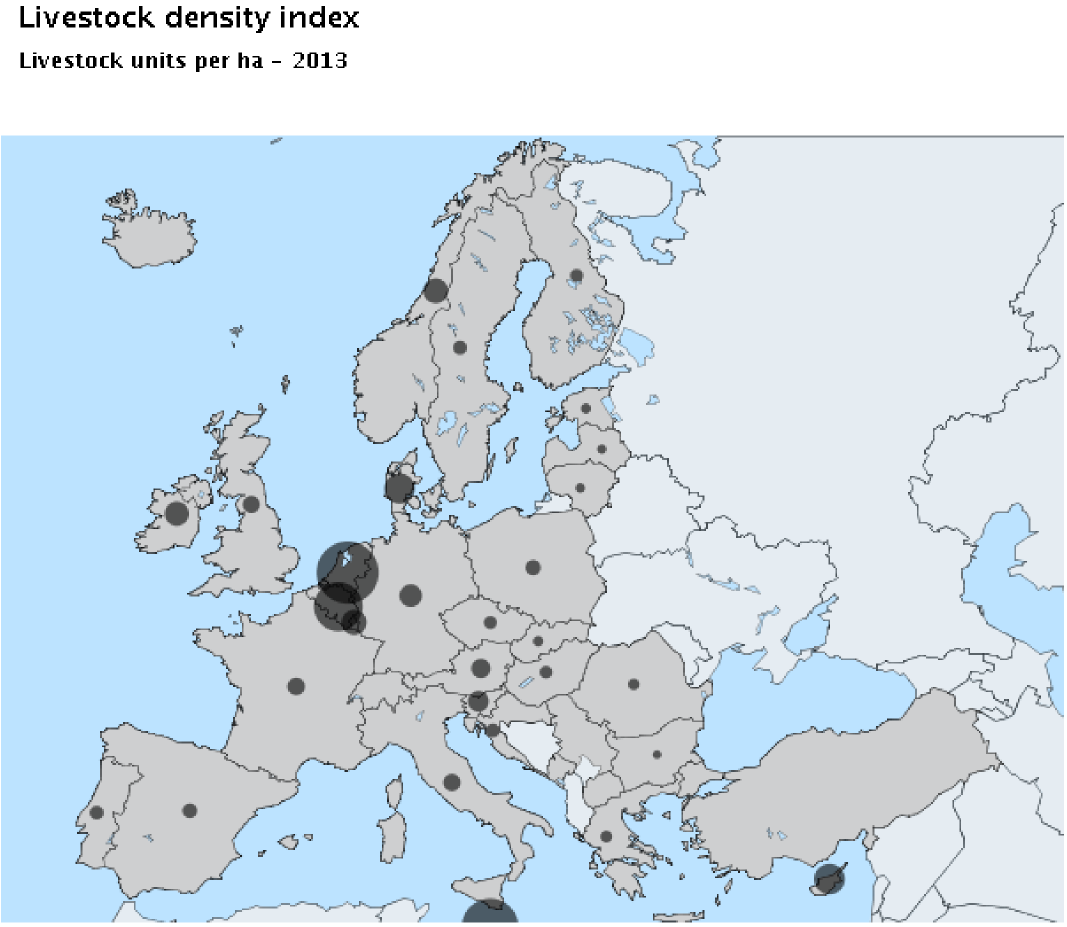

Figure 3: Livestock densities in the EU in Livestock Units (LSU) per hectare of Utilised Agricultural Area (UAA) for 2013

Source: (EUROSTAT, 2016)

Arable land

Considering that the Netherlands is a relatively small country in terms of land surface, arable land is a scarce natural resource. Any form of commercial land use in the Netherlands is likely to need high profitability, since land prices are relatively high. The use of arable land focuses on high productivity (i.e. yields) per hectare. Arable land is used for the production of biomass, for example for the production of foods and feeds. In order to ensure high productivity per hectare, good soil fertility management is also required. Fertilisation is typically done with a combination of (untreated) animal manure and mineral fertilisers. Animal manure serves as a basic source of macro- and micro-nutrients for crops. The drawback of using untreated animal manure is that it delivers only a fixed mix of required nutrients (e.g. N, P and K) per batch. Any deficiency or surplus in a given nutrient has to be compensated by any other form of fertilisation. Here fossil fertilisers are most often used to create an adequate fertilisation menu. Soil type, cropping strategy and other environmental conditions determine how much and what type of fertilisation is needed for a given hectare of land. How much animal manure can be submitted to land is also bound by a set of norms (embedded in the EU Nitrates Directive) regarding the supply of nitrogen and phosphates to agricultural soils. These norms are expressed in kg of Nitrogen (N) and Phosphates (P) per hectare.

According to data from the CBS (see Table 13), the total amount of agricultural land in the Netherlands decreased from 63.444 ha in 2000 to about 50.509 ha in 2015. This is a reduction of about 20% in 15 years' time. The total amount of grassland has remained rather stable in the same period. These are the two main farmland categories that provide the Dutch livestock sector with space for 'placing' animal manure.

Table 13: Land use in the Netherlands for various years (in are)

	2000	2005	2010	2013	2014	2015
Farmland, total	197550427	193769503	187231940	184757142	183901711	184574562
Agriculture	63443967	60405424	54207080	53241217	51727912	50508755
Horticulture (open ground)	8106079	8139184	8707297	8635971	8710145	9104183
Horticulture (glass)	1052088	1053966	1030749	981747	948820	920783
Grassland & fodder	124948293	124170929	123286814	121898207	122514834	124040841
Non-farmland, total	**15187102**	**13464321**	**14627654**	**16130305**	**16188484**	**17014954**
Permanent forest	3932354	983892	877551	894684	934157	667002
Farmland (not in use/idle)	878123	2382502	1245912	741979	667604	246300
Fast growing wood/temporary forestland	260659	278811	279452	328724	315797	239193
Other non-farmland	10115966	9819116	12224739	14164918	14270926	15862459

Source: (CBS, 2016k)

Land use for energy crop production is rather limited in the Netherlands. This is partly because the existing forms of land use are already well established, but also due to the high land prices and the relatively low profitability (under uncertainties) regarding bioenergy investments. The dominant forms of land use of farmland are the cultivation/production of foods (potatoes, sugar beets, etc.) and feeds (e.g. roughage, like grasses and maize). On top of that there is increasing 'competition' for other uses of land (e.g. infrastructure, nature) which all makes farmland a relatively scarce resource in the Netherlands.

Energy resources: focus on biomass

Interestingly, since the Netherlands is a relatively small country, the availability of domestic biomass is rather limited. The increasing domestic demand of biomass for energy purposes is therefore mainly covered by importing a large amount of biomass. The current level of import dependence depends on the specific subcategory of bioenergy. Table 14 shows for various biomass-to-energy categories the amount of bioenergy produced, and also provides a qualitative assessment of the level of biomass import dependence.

Table 14: Biomass-to-energy subcategories, energy production and estimated biomass import dependence

Final consumption of renewable energy – BIOENERGY	In PJ in 2015	Assessment of import dependence

Total biomass	80.2	-
Waste incineration (share of organic waste)	20.3	Predominantly indigenous resource, however due to overcapacity some waste is already imported from abroad.
Biomass co-firing in power plants	6.9 (2013)	Mainly imported wood pellets from North-America.
Biomass use in households	18.6	Predominantly indigenous resource, mostly stemming from local wood resources, and forest maintenance.
Biomass stoves (companies) -	5.3	Predominantly indigenous resource.
Biomass stoves (companies) -	8.7	Predominantly indigenous resource.
Total biogas	10.8	Predominantly indigenous resource, including landfill gas, biogas from waste water treatment plants, manure co-digestion and other biogas options.
Total liquid biofuels	13.3	Mainly imported.

Source: (CBS, 2016c)

The remaining domestic potential to extract more wood for bioenergy from the Dutch forests is quite limited, and the already intensive use of arable land for biomass production for food and feed production leaves limited remaining potential for the production and use of domestic biomass for energy purposes. Aside from (unused) grasses, animal manure is one of the biomass resource categories with substantial remaining (technical) domestic potential for energy production.

With regards to environmental protection, the Netherlands government has a broad range of environmental priorities/ambitions. For most of these priorities specific government targets are in place which go hand in hand with an active policy framework. Environmental priorities are linked to air quality, soil/surface water quality protection, nature protection/conservation, and climate change. The key environmental priorities in relation to the case study (Integrated Manure Management) are presented in Table 3 (section 2.1.1). On top of that there are a number of relevant priorities (and provisions) with regards to other kinds of pollutants that can damage the health and safety of humans/animals (e.g. heavy metals, pharmaceutical materials, etc.).

1.2.3 Economic priorities

The growth strategy of the EU for the period 2010–2020 aims to realise the targets set for 2020 in the areas of climate and energy, while supporting employment, innovation, education and social cohesion. In the Netherlands this has been translated into the following national economic targets (EC, Europe 2020 in the Netherlands, 2013b):

- at least 80 percent of the population aged 20-64 to be employed;
- 2.5 percent of GDP to be invested in R&D;
- a maximum of 8 percent early school-leavers;
- 40 percent of 30–34-year-olds to have completed higher education;
- 100 thousand less people at risk of poverty and social exclusion.

The Dutch Energy Agreement (first introduced in section 1.2.1.1) aims to create at least 15,000 full-time jobs (most of them in the early years after the Agreement is signed). The Agreement also set out an economic target to be achieved by 2023, including the improvement of the competitiveness of companies, improvement of the investment security and innovations supports, reduction of the costs of energy for households and businesses and the increase of investments between 2013 and 2020 in the form of subsidies, infrastructure costs and private investments.

The GDP in the Netherlands was about 680 billion Euros in 2015 which is about 40,500 Euros per capita (CBS, 2016l). The Dutch economy is still recovering from the financial crisis started in 2008.

The historic trends of GDP, spending and investments expressed in % are shown below in Table 15 (CBS, 2016m). The initial fall in economic output in 2009 was rather sharp and was driven by a collapse in foreign trade and fixed investment. GDP has shrunk by almost 4% in 2009, while government spending still followed a positive trend. Households spending and investments both declined by about 0.8 and 1.6%, respectively. A short-lived recovery in 2010 was followed by a renewed decline in GDP in 2012 and again in 2013. Both private consumption and fixed investment declined, in combination with the downturn of the housing market from 2010 onwards and by rising uncertainty regarding pension benefits. The economic fall-out, short-lived recovery and renewed decline are highlighted in light green.

Table 15: Historical economic growth factors in the Netherlands between 2000 and 2015

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GDP	4.2	2.1	0.1	0.3	2.0	2.2	3.5	3.7	1.7	-3.8	1.4	1.7	-1.1	-0.2	1.4	2.0
Total spending	1.8	1.7	-0.1	0.2	0.5	1.1	2.2	2.4	1.7	-1.5	-0.4	0.3	-1.9	-1.0	0.4	1.3
Household spending	1.0	0.6	0.2	0.1	0.3	0.4	-0.4	0.6	0.3	-0.8	0.0	0.0	-0.5	-0.4	0.0	0.4
Gvt. Spending	0.6	0.8	0.7	0.6	-0.2	0.3	1.7	0.7	0.8	0.9	0.3	0.0	-0.3	0.0	0.0	0.0
Investments	0.2	0.3	-1.0	-0.5	0.4	0.4	0.9	1.1	0.6	-1.6	-0.7	0.3	-1.1	-0.6	0.4	0.9

Source: (EC, 2013b)

*Note: The forecasted GDP growths for 2016 and 2017 are 1.7 and 2.0%, respectively

Besides helping the young and improving education and employment, the integration of minorities is a daunting political challenge (Ministry of Social Affairs and Employment, 2016). People of for example Turkish or Moroccan origins are more likely to have difficulties with finding a job compared to ethnic Dutch citizens; therefore, the government encourages new immigrants to take integration and language courses to improve their chance on the job market and their position in the society.

Social security system is another important political issue since the number of over-65s relative to the working population rises rapidly. The government would like to keep the social security system affordable and for this tries to adopt reforms and cutbacks to reduce the inflow of new recipients of social benefits. Reintegration of invalids who found to be fully or partially fit for work is also one of the priorities of the government.

1.2.4 Societal priorities perspective on climate change

In 2015, a group of Dutch citizens sued their government over the failure to act on climate change (Urgenda, 2015). This was the first time ever that climate change as an issue was taken to court under human rights. Given the scale of the threat posed by climate change,[18] the group of concerned citizens and climate campaigners argued that emission-cutting pledges are inadequate and the government should do much more to mitigate climate change. The court ruled that the government`s plan to cut emissions by 16% relative to the emission level in 2005 (by 2020) is indeed unlawful and ordered the government to cut emissions by at least 25% within 5 years. The government has decided to appeal the court`s decision.

At the same time, the Urgenda law suit must not be interpreted as wide consideration of the importance of climate change and mitigation actions among the Dutch population. While, for example, in 2006-2007, Al Gore’s documentary ‘An Inconvenient Truth’ received a lot of attention within different groups of society, the financial crisis and consequent economic recession caused a strong shift of attention to economic and financial issues, rather than climate change. The UN Climate Summit of Paris in 2015 received a lot of media attention, but experienced climate policy stakeholders indicated that, even though people are more aware of climate change, there is still lack of urgency about avoiding climate change impacts (JIN Climate and Sustainability, 2016).

In some cases, citizens even opposed climate change mitigation actions. For example, the development of wind power parks in the country has resulted in over 130 citizen committees protesting against this technology (Hofman, 2014). This protest is not limited to onshore windmills and parks located nearby residential area (e.g. villages, small cities), citizens have also started to protest against larger-scale off-shore wind parks which are on a far longer distance from where they live. In general, citizens support climate change actions and renewable energy, but the NIMBY (not in my backyard) or NAMB (not at my beach) effects are rather significant when it is about wind parks. Biogas plants (due to the fear of noise, bad odour and landscape pollution) meet similar resistance. At the same time, it has also become clearer that social acceptance of wind power increases when people get a stake in the investment and obtain a share in the revenues (Hofman, 2014). Considering the use of solar energy and PV installations, the public perception is generally positive, but it often hindered by the lack of investment and suitable rooftops (in terms of direction to the sun) and occasionally by aesthetic concerns (e.g. panels do not fit within the surrounding or do not look attractive on the roof). Options to improve integration of solar panels

[18] Nearly a quarter of the Netherlands is located below sea-level which means that the country should be an early adopter of climate change mitigation and adaptation strategies.

for larger acceptance are, for example, PV roof tiles and shingles, differently shaped or coloured panels. Therefore, from a social, public acceptance perspective, solar PV can be considered more acceptable than wind power, unless social participation in wind farms is well arranged.

Currently, the Netherlands has over 17 million inhabitants. With a population density of 488 people per km^2, the Netherlands is the most densely populated country of the European Union and one of the mostly densely populated countries in the world. This also explains why it is so important to consider space needed for renewable energy options and why wind farms and biogas plants meet resistance by the population. Densely populated areas are, on the other hand, relatively suitable for solar PV which to a large extent can make use of existing buildings. Only when solar PV is considered in larger scale solar parks, the issue of spatial planning in a densely populated area can become a public acceptance issue.

1.2.5 Politics of energy development priorities

The short term orientation of the Dutch government (up to 2020) is to ensure that the (binding) national targets for renewable energy and climate are being met. The main policy instruments to enable this are a feed-in support scheme (called the SDE+) and the European Emissions Trading Scheme (EU ETS). The key objective of both schemes is to achieve the energy and climate targets at the lowest possible cost. The SDE+ budget has been increased considerably in recent years as the speed and scale of implementation of new projects was not on track to be able to meet the 2020 target for renewable energy. Local/regional governments generally are more focused on ensuring that any new (renewable energy) project or initiative meets local health, safety and environment standards. In several cases the priorities/ambitions of the local government were not aligned with those of the national government.

The long term energy policy of the Netherlands government is to switch to a sustainable economy with low carbon energy supplies by 2050 (Ministry of Economic Affairs, 2016b). To increase the reliability of the energy supply (while keeping consumers` and businesses` energy bills under control), the government plans to adopt a mix of energy generated from renewable (like biomass, wind and solar which the government supports via subsidy schemes, including feed-in tariffs) and traditional sources such as gas, coal and oil. As it was mentioned before, for achieving the Dutch climate goals as part of the EU climate and energy packages, the country`s dependence on fossil fuels needs to be reduced. However, for technical lock-in reasons (see Table 6: Dutch energy sector overview: shares, efficiency rates, technology life cycles, lock-ins)- within the last ten years, three new coal plants were commissioned and built - and the Dutch natural gas endowments and infrastructure, it is likely that fossil fuels (coal and/or gas) will still have a long term and important role in the energy supply in the following decades.

From a political perspective, the Netherlands coalitions, forming the cabinets of ministers since 2002 (when the climate-progressive ‘Paars II’ coalition ended), have been conservatives from a climate perspective. The 2002 cabinet led by Prime Minister Balkenende even abolished the position of Minister of Environment. Environment become the responsibility of a deputy minister. The cabinets led by Prime Minister Rutte, since 2010, have considered environment and climate change as a topic under Infrastructure. Most of the Dutch environmental and climate policies consist of implementation of EU Directives with little additional resources for domestic climate change mitigation actions. Recently, in October 2016, the government organised the National Climate Summit, attended by 1700 participants, which created a platform to launch a series of (public-private and private) initiatives to reduce GHG emissions. A week later though, one of the coalition parties took the position to postpone ratification of the Paris Agreement as it desired further discussion on the text. This is the first time in the history of international climate policy making that the Netherlands will, if at all, ratify a climate agreement after it has entered into force. It is noted that the EU as a whole has submitted an instrument of ratification on the Paris Agreement, thereby representing the Member States.

1.2.6 Conflicts and synergies of priorities

1.2.6.1 Energy sector

While the government has its binding targets for 2020 and would like to have a sustainable economy by 2050, the adoption and development rate of renewable projects do not seem sufficient enough. In addition, as the court decision pointed out, the government`s current GHG emission reduction target is inadequate and more emission cuts should be achieved.

In summary the following issues needs to be considered:

- Lack of public acceptance
- Lack of true urgency by population
- Densely populated areas make spatial planning for renewables more complex
- Government coalition are at best passively supportive to climate change options.
- Most environmental policies are formulated at the EU level, so that domestic additional actions are perceived as less urgently needed.

1.2.6.2 Livestock and agriculture sector

When focusing on the livestock sector and its environmental impacts, it is clear that various environmental policy targets and objectives apply (see Table 3). A more sustainable livestock sector could contribute to:

- Renewable energy targets (digesting manure to produce renewable energy)
- Air quality (reducing NH_3 emissions)
- Mitigating climate change (reducing CH_4 emissions)
- Better re-use of soil nutrients (N and P_2O_5)

For most of these environmental objectives the Dutch government has binding targets. However, for each specific policy objective, typically a dedicated set of policy instruments is implemented. This mix of policy instruments does not automatically result in a cost-efficient trajectory towards a sustainable society. In many cases, specific technological actions are implemented to meet 'just' a single environmental objective, whereas for IMM (and likely for many other actions in other sectors) there is a need to solve these multidimensional environmental issues all at once in an integrated manner. Although, promoting an integrated policy approach towards environmental protection is not new, it is likely to be challenging from the political and regulatory perspective. This is due to the fact that the timelines and relative urgencies regarding the individual environmental impacts do not run in parallel.

1.3 The Human Innovation System Narrative - Solar PV

1.3.1 Overview of the development of solar power generation

As it was mentioned above, the Netherlands is lagging behind on the implementation of renewable energy technologies and therefore reaching its 14% renewable energy target in 2020. One option to accelerate the implementation of renewables in the Netherlands is to intensify the implementation of solar PV panels.

Solar power has recently become increasingly popular due to the decline in solar panel prices, the variety of policy measures implemented by the government, and also due to the lower interest rates on deposit account so that the opportunity costs of solar investments (missed interest revenues) have become lower. The decline in solar panel prices over time is shown in Figure 4 below. The average price, estimated on the basis of prices in Germany, Japan and China, has dropped from 2.5 €/Wp to about 0.6 €/Wp from 2010 until 2016. This already makes investments in solar PVs more attractive, but still not enough to make up for the price difference between fossil and renewable energy prices, especially for large-scale project developers.

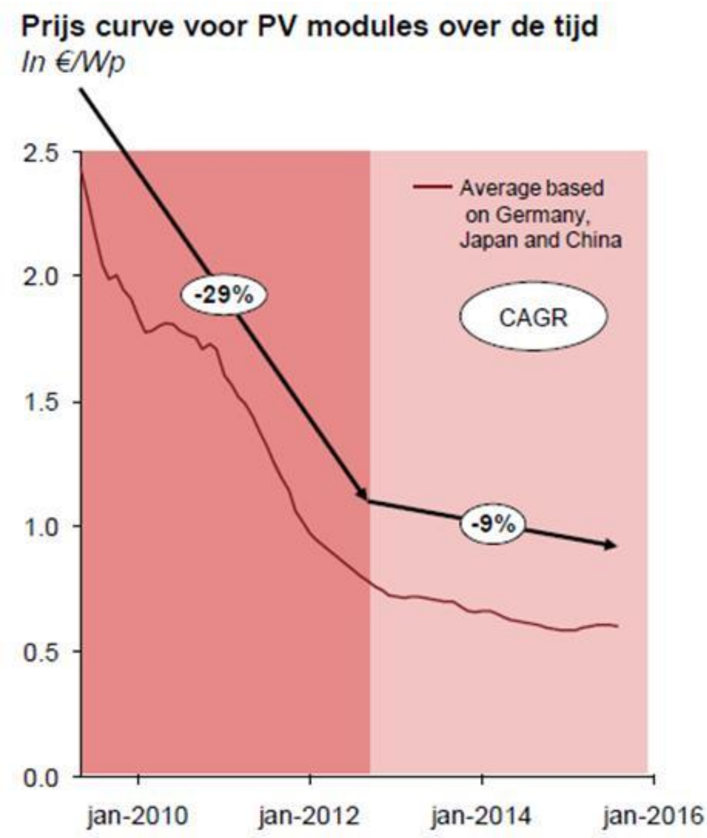

Figure 4: Cost curve for solar PV modules between 2010 and 2016

Source: (PwC, 2016)

The total installed capacity in the Netherlands has tremendously increased between 2010 and 2015, from 90 MW_e to 1485 MW_e (CBS, 2016n). However, this falls still short of the potential of solar energy (shown in Table 16), as it has been calculated for 2020 and 2050 by Holland Solar in 2015 based on the total size of available rooftops, public buildings and parking areas.

Table 16: Potential of solar energy for 2020 and 2050 (in PJ/year)

Potential of solar energy in PJ/year		
	2020	**2050**
Households	13	92
Industry & utilities	1.5	77
Agro sector	1.5	35
Total	**16**	**204**

Source: (Holland Solar, 2015)

Presently, solar energy gives only 0.5%, about 4 PJ/year, of the total renewable energy use in the Netherlands. Based on the predictions in Table 16 above, solar energy could be increased potentially 4-folds and 50-folds by 2020 and 2050, respectively.

Solar power generation is currently almost 100% decentralised, based on small-scale rooftop panels, but this is expected to change since large-scale solar projects have been included as an eligible category within the national feed-in subsidy scheme from March 2015. About 70% of the solar power is generated by households (~250,000) and 30% by businesses. The potential is much larger than this since there are over 7 million Dutch households (however, not all equipped with a suitable rooftop). The potentially available area for solar PV at household rooftops was estimated at about ~400 km^2 while the potential for public and private areas (for the development of large scale projects) is about 200 km^2 each (Holland Solar, 2015).

To utilise this remarkable potential for solar energy generation, the government needs to ensure that policy measures remain transparent and predictable on a long-term basis since investments in solar projects have relatively long payback times.

1.3.2 TIS life cycle value chain: a cradle to grave analysis

The Dutch value chain for solar PV for electricity production consists of the following elements, actors, services and infrastructures:

a) **Energy resource extraction**: the life-cycle of solar panels starts with mining the main building block of the panels which is called silica (or silicon dioxide or quartz).
b) **Solar PV production:** Today, more than half of the solar panels are manufactured in China which gives a large boost to its economy but in the same time it also takes its toll on the environment and the health of workers. China among others like Malaysia, Philippines and Taiwan (the other large producers or solar panels) typically does the least effort to protect the environment and its workers (e.g. frequently there is no proper waste recycling and no protection for workers). A study from 2014 showed that a solar panel`s carbon footprint is about twice as high when made in China and used in Europe than those that are locally manufactured and utilised (Darling, 2014).
c) **Solar PV retailing**: there are multiple solar panel retail companies in the Netherlands. They not only sell the panels but also often provide guarantee, maintenance and repair services. There are also companies that provide solar panel leasing options.
d) **Solar PV installation**: solar panels can be installed by retailers, but also by construction companies and specialised businesses.
e) **End-use**:
   - *Small-scale*: built-environment equipped with solar panels, including households, businesses, housing corporations and municipalities.
   - *Large-scale*: the large-scale use of solar panels is supported by subsidy for upscaling in the next couple of years.
f) **Power generators (energy conversion technology systems):** As it was already discussed in the introductory section and shown in Table 7, most of the electricity is produced from using fossil fuels (mostly natural gas and coal) in large power plants and only a smaller fraction is generated from renewable sources (about 1% from solar panels). Households that own solar panels can be end-users and power suppliers at the same time if they feed surplus power generation back to the electricity grid.

g) **Power trading**

h) **Power transmission & distribution:** there is only one transmission system operator (TSO, called TenneT) in the Netherlands with the ultimate task to manage the national transmission grid and maintain the balance between the electrical supply and demand. There are 8 distribution system operators (DSOs) responsible for the distribution of electricity at various parts of the country.

i) **Dismantling and recycling of solar panels:** the EU has made the collection of old solar panels mandatory since 2014. It is rather difficult to dismantle solar panels as the buildings blocks are manufactured together very tightly. Therefore, nowadays, only the frame and electrical connection box are removed while the rest is simply crushed. The shattered glass and pieces of metals are recycled whereas the remnants are treated as waste and get dumped.[19]

j) **Facilitating/(limiting?) services and infrastructures**
   a. Netherlands Enterprise Agency
   b. Ministry of Finance
   c. Ministry of Infrastructure and the Environment
   d. Municipalities and Provincial governments
   e. Banks
   f. NGOs and consultancies
   g. Authority for Consumers and Markets (ACM)

1.3.3 Enabling environment: policy mixes in the socio-economic system)

The tables below present overviews of how EU environmental priorities have been translated into Dutch national policies (Table 17) and how these policies have been implemented with policy instruments.

Table 17: EU Environmental priorities and corresponding EU and national policies in the Dutch solar PV sector

EU environmental priorities	Dutch National Policies	EU Directive Reference
1. "Preventing climate change"	P1: Clean and Efficient programme P2: Environmental Management Act (permitting) P3: Environmental Taxes Act P4: Stimulation of Sustainable Energy Production (SDE+) P5: Electricity Act P6: EPC norms for buildings	- Renewable Energy Directive (RED) - Energy efficiency Directive (EED) - Electricity Market Directive - Energy Taxation Directive - Energy Performance of Buildings Directive (EPBD)
2. "Maintain and restore biodiversity"	P2: Environmental Management Act P7: Nature Conservancy Act	- RED -

[19] https://www.ecn.nl/nl/nieuws/item/solar-panels-not-yet-sustainable-enough/

3. “Substantially reduce natural resource use”	P3: Environmental Taxes Act P8: Landfill Tax P9: Discarded Electrical and Electronic Waste Regulation (AEEA)	- Energy Taxation Directive (ETD) - Landfill Waste Directive - Waste Electrical and Electronic Equipment Directive (WEEE)
4. “Make the EU a healthy place to live”	P5: Air Pollution Act (APA)	- Air Quality Directive

Table 18: Dutch policy instruments that directly or indirectly impact the solar PV sector

Policy themes	Dutch National Policy Instruments			
Energy	Environmental Taxes Act- net-metering	Energy Investment Allowance (EIA)	\`Postcoderoos\` regulation for corporations	VAT refund for the purchase and installation costs of solar panels
		Electricity Act-net-metering	EPC norms (Renewable energy in energy performance standardisation)	Spatial Planning Act
		SDE+ subsidy	Asbestos off, solar panels up (for farmers)	Gvt. co-funding for renewable projects
Climate			Climate agreement between municipal authorities and the government	
Air	Air Pollution Act			
Waste/ resource use	AEEA regulation	Landfill tax		
Biodiversity	Nature Conservancy Act			

The most important measures are the net-metering and tax benefits for small-scale solar PV owners and the SDE+ (Stimulation of Sustainable Energy Production) subsidy for large-scale project developments (Table 18).

The SDE+ scheme is a premium feed-in tariff scheme that compensates producers of solar energy for the difference between the cost price of fossil energy and solar energy for a period of 15 years (RVO, 2016). Only projects with a large-scale energy connection (> 3*80 Amp) are eligible to this subsidy. Producers with smaller energy connection (< 3*80 Amp) may consider acquiring a large-scale energy connection to be eligible for the subsidy, the related costs for acquiring a large-scale energy connection can be considerable.

The installation of solar PVs on households’ rooftops started to gain momentum and boom after the introduction of net-metering (in Dutch called \`saldering\`). Net-metering is a powerful financial incentive for small-scale solar power generators and users (e.g. households and businesses equipped with solar PVs, with a small-scale energy connection of 3*80 Amp), as it allows feeding unused electricity from solar PV into the power grid and receiving financial benefits for that (lower energy bill and tax exemptions). It is frequently pointed out that due to net-metering, the Netherlands government (i.e. Ministry of Finance) misses potential tax revenues. This is because eligible households and businesses do not pay energy tax, VAT and sustainable energy contribution over the self-generated and used electricity (the consumer only pays energy tax over the remaining share of the `traditionally` generated and supplied electricity). This income loss is expected to grow as more and more panels are installed on rooftops. For this reason, the government raised the question whether this measure is the best and most cost-effective option to stimulate the installation of solar PVs. Recently, the government announced its intention to evaluate the policy of net-metering in 2016 (Solar Magazine, 2016).

Before 2014, there was a limitation (5000 kWh) on the amount of electricity that could be deducted from the energy bill. This has been changed in 2014 to a more flexible limit that is determined for everyone by their own energy suppliers. Consumers who feed more electricity into the grid than they take from it, receive a financial compensation (`terugleververgoeding`) from the energy company for the net electricity delivered to the grid. As it was mentioned, due to the declining production and use of fossil fuels-based electricity, the treasury has lower energy tax revenues, which implies that the government needs to find alternative ways to cover the loss of this type of revenue. Nowadays, net-metering will remain in effect till 2020, but it is presently unclear whether and how it will continue after that. There might be a transition phase before another type of compensation is applied or it might be completely abolished. This however creates a large amount of uncertainty and discourages investments in solar panel installations.

Besides net-metering and the SDE+ subsidy, various types of loans and tax incentives are intended to support investments in solar PVs. One of the most important tax incentives is the VAT refund which ensures that 21% of consumers purchase costs of solar PVs (i.e. including 21% VAT) are refunded to consumers. Another important tax incentive is the reduced tariff for the collective production of renewable energy (in Dutch: `Verlaagd tarief voor collectieve opwek`), called the `postal code rose` (in Dutch: `postcoderoos`) regulation. Under this regulation, associations of owners located in the same postal code area can jointly invest in solar PV installations while receiving certain tax benefits. In such a way, they can jointly produce solar energy which is then sold to an energy supplier while the energy sold is credited to the energy bill of the participants. This can be an attractive option for households whose rooftops are not suitable for solar PV panel, because of the orientation of the house (i.e. south-west or north) or larger dormer windows.

Besides fiscal incentives, regulations on the energy performance of houses are also important policy tools. Energy performance requirements have been in place for new buildings in the Netherlands since 1995. They are updated on a regular basis, moving towards NZEB targets for 2020. The main requirement for the energy performance of new buildings is the compliance with the energy performance coefficient (EPC). A project developer must demonstrate full compliance with the energy performance requirements to receive a building permit for a new building or a major renovation.

Depending on the region or province, there might be additional subsidies financing and leasing options that could further stimulate the investments into solar PVs.

Spatial planning is another important issue when considering the installation of solar panels, especially for large scale applications. For the small-scale solar pathway, rooftops are often not suitable for the installation of solar panels due to shading or positioning. As a densely inhabited country (see above), it might be more challenging to develop large scale solar projects compared to smaller scale initiatives. The public perception for installing solar panels of rooftops is overall positive and only occasionally hindered by aesthetic concerns. For large-scale projects, public acceptance can be high if solar panels are installed on state owned and industrial lands. However, public acceptance may be lower when agricultural lands or lands located close by communities are converted for such purposes (see the above discussion on the NIMBY effect for wind power). Recently however, a sizeable amount of (non-agricultural) public and private land and water surface has been identified for installing large amount of solar panels (Holland Solar, 2015), (Rijkswaterstaat, 2016).

1.3.4 Enabling environment: government institutions

The government of the Netherlands includes the King and the Ministers while the Cabinet consists of the Ministers and the State Secretaries. Figure 5 shows the main institutions relevant for the TIS value chain in the Netherlands.

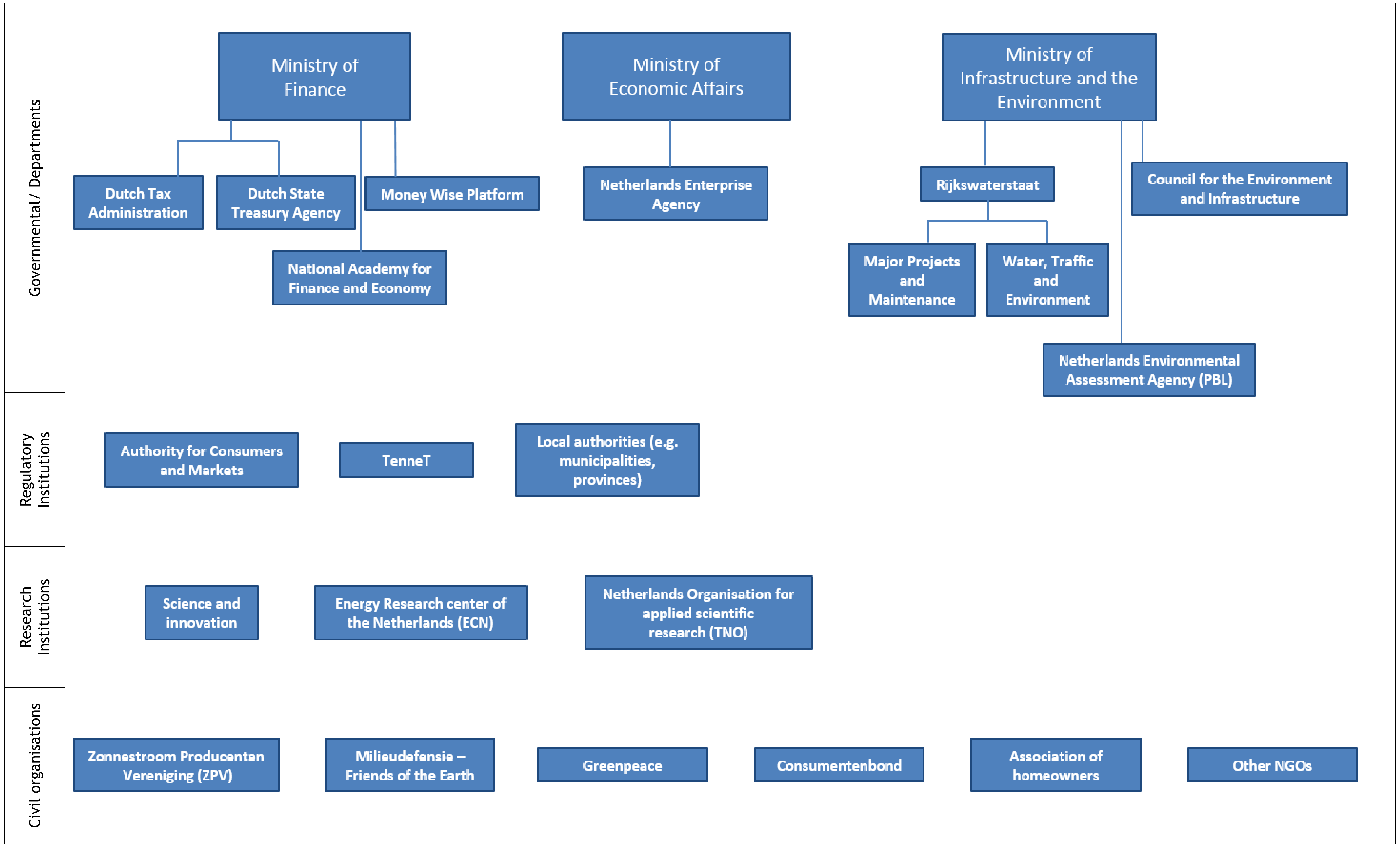

Figure 5: Major institutions for solar power in the Netherlands

The Ministry of Finance guards the national treasury and oversees the spending of governmental resources as well as the quality of financial institutions. It also works on equitable and solid tax legislations while the Dutch Tax Administration, as part of this Ministry, levies and collects taxes.

The Ministry of Economic Affairs promotes entrepreneurial business climate by paying attention to nature and the environment and encouraging the cooperation between research institutes and businesses. With the SDE+ subsidy it also intends to stimulate the development of sustainable energy projects). The Netherlands Enterprise Agency (RVO) is part of this Ministry, encourages entrepreneurs in sustainable, agrarian, innovative and international business by finding business partners, helping with grants and compliance with laws and regulations while being in close cooperation with domestic and foreign governments, knowledge centres and other international organisations.

The Ministry of Infrastructure and the Environment is committed to maintain and improve the quality of the environment, including air and water quality, the network of roads, railways, water- and airways as well as effective water management to protect against flooding. Rijkswaterstaat, the executive agency of this Ministry is the responsible entity for the main road network, waterway networks and systems extend into the social environment.

The Netherlands Environmental Assessment Agency (PBL) is part of the Ministry of Infrastructure and the Environment. It is an autonomous research institute focusing on issues related to environment, nature and spatial planning. PBL is also the national institute for strategic policy analysis, aiming at improving the quality of political and administrative decision making by providing detailed analyses and evaluation of the environmental issues.

The Authority of Consumers and Market (ACM) is the independent national regulatory authority for energy. Its ultimate goal is to prevent and resolve market and consumer problems by creating a level playing field with overseeing business and sector competitions (including the energy sector), sector specific regulations and enforcement of consumer protection laws. In case of any issues, consumers may contact this authority via the ConsuWijzer[20] for free information and advice. Businesses may turn to ACM in case they notice foul play by others or if businesses or organisations wish to merge. In this case, ACM assesses what the effects of these actions will be for the competition and consumers.

TenneT is the sole electricity transmission system operator (TSO) in the Netherlands responsible for operating the High Voltage Network, including the maintenance of interconnections and balancing supply and demand. Any party that wishes to supply electricity in the country must be acknowledged and must enter into an agreement with TenneT.

Local authorities such as municipalities and provinces might impose their own regional rules and regulation as well as provide additional incentives (both financial and informational/educational)

[20] https://www.consuwijzer.nl/

for the development of renewable projects and improvement of energy efficiency. Naturally, this varies depending on the location of the individual projects.

ECN and TNO are two of the leading research centres in the Netherlands. ECN is one of the largest energy research institute in Europe, providing technology and knowledge developments for enabling the transition to a sustainable energy economy. TNO is also an independent research organisation that aims at connecting people and knowledge to create innovations that boost the sustainable development of industry and the well-being of society.

Civil organisations such as Greenpeace, Friends of the Earth are independent organisations that aim to change attitudes and behaviour to facilitate the protection and conservation of the environment. Other Dutch civil organisation such as Consumentenbond, Association of homeowners and Zonnestroom Producenten Vereniging (solar power producers' association) provide independent (without commercial interest) information, advice and in some cases even financial benefit to consumers to improve sustainability of Dutch homes.

1.4 The Innovation System map – solar PV

The system elements identified in chapter 1.3 are combined in a system map as presented in Figure 6.

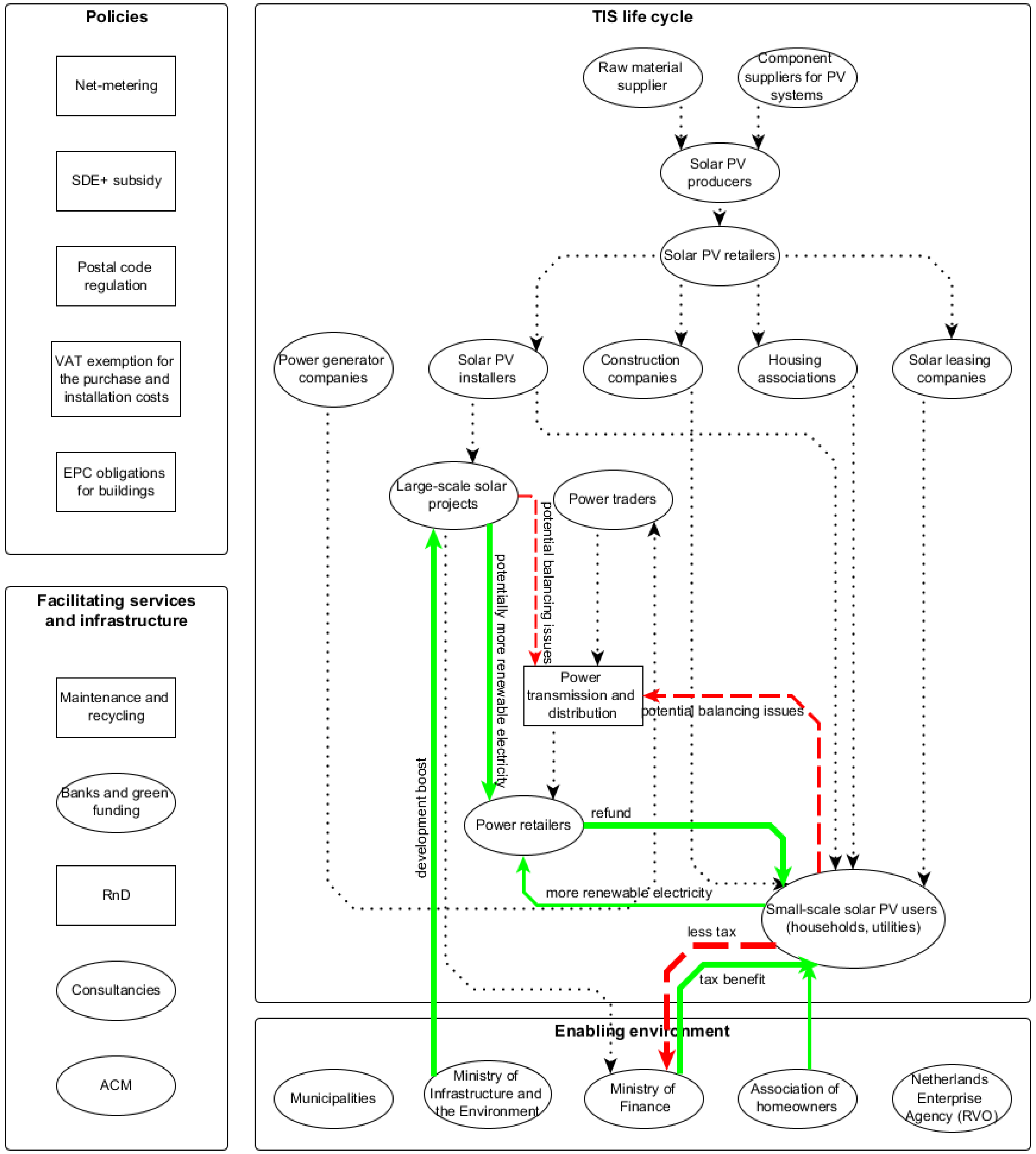

Figure 6: Preliminary system map for the Dutch solar PV sector

The system elements identified in chapter 1.3 are combined in a system map as presented in Figure 6.

Figure 6 shows the main actors and policies for the Dutch solar PV sector. In a nutshell, both technological options -small and large-scale- solar PV have the potential to generate more renewable electricity and therefore could potentially accelerate meeting the Dutch renewable energy goals. However, at the same time both technological options carry the risk for potential balancing issues in the electricity grid that need to be considered.

For small-scale solar projects, net-metering is a key policy since it provides a financial incentive for households to invest and install solar PVs on their rooftops. One of the financial incentives is the tax benefit via the Ministry of Finance (households do not have to pay tax over the self-generated electricity) while the other is the benefit from power retailers granted for the electricity that is not self-consumed but fed back to the electricity grid. On the other hand, this generates less tax income for the Ministry of Finance.

Large-scale solar projects could rapidly develop by the assistance of the Ministry of Infrastructure and Environment (Rijkswaterstaat) since they own and/or manage a large part of state owned lands. This could accelerate the permitting and installation processes of large-scale development plans (due to the ownership and the readily available infrastructure).

1.5 Stakeholder engagement – Solar PV

Table 19 lists the stakeholder interviewed thus far in the solar PV case study.

Table 19: Stakeholder Engagement

Type of stakeholder	Position in the organisation* (keep this generic so it doesn't risk stakeholder anonymity)	Economic sector**	Type of engagement***	Month and year contacted
1. National government	Advisor	Climate/energy	Interview	October, 2016
2. Research/ consultancy	Professor	Energy	Interview	November, 2016
3. Research/ consultancy	Senior researcher	Energy	Interview	November, 2016
4. Business	Vice president	Energy	Interview	October, 2016
5. Research	Assistant professor	Environmental psychology	Interview	November, 2016

* Government (national / subnational), research / consultancy, business, other (specify)
** Energy, Industry, transport, environment, agriculture / forest, financial / trader, other (specify)
*** Interview, focus group, workshop, survey etc.

1.6 The Human Innovation System Narrative – Integrated Manure Management in the livestock sector

1.6.1 Overview of the development of the livestock sector

The livestock sector is well-connected to the Dutch society and cuisine. Especially, Dutch dairy products, like cheese, milk and baby-milk powder, are renowned nationally and internationally. The Netherlands:

- is the 2nd largest exporter of agricultural products and services after the United States,
- has the 7th largest dairy cattle herd in the EU, while it is the 4th largest producer of milk,
- is also the largest producer of veal in the EU, and
- has the 5th largest pig herd in the EU.

These agricultural-livestock activities all take place in a relatively small country (in terms of land-size). As a result, the Netherlands has one of the highest livestock densities in the EU (Figure 3: Livestock densities in the EU in Livestock Units (LSU) per hectare of Utilised Agricultural Area (UAA) for 2013Figure 3) expressed in terms of Livestock Units per hectare of arable land. Therefore, it should be no surprise that there are serious environmental (and increasingly social) effects associated to the Dutch livestock sector.

The need and urgency for a more sustainable livestock sector is not new. There already is a longstanding tradition of environmental regulations with regards to this sector. The first EU-level environmental regulations on air and water date back to the early 80s, well after the launch of the Common Agricultural Policy (CAP) in 1962 (see Table 1). After that environmental regulations on climate and renewable energy entered into the policy mix.

More recently, and especially after the abolition of the EU milk quota system[21], a range of environmental harmful emissions linked to the livestock sector have increased. This trend is making it more difficult to meet a series of binding targets (see Table 2 / Table 3). Given the broad range of environmental impacts, any low-carbon transition pathway in the Dutch livestock sector should not only address the issue of GHG emissions, but also reduce the emissions of other pollutants.

Within the Dutch livestock sector throughout history there have been several projects and programmes aimed to improve the overall sustainability performance. These programmes have had a mixed effect. One of the drawbacks of a number of these programmes have been that they

[21] On the 31st of March 2015 the EU milk quota system was abolished, allowing individual dairy farmers to determine how much milk they want to produce. In the Netherlands, this resulted in a drastic increase in the production of milk.

addressed only one single pollutant or the supporting policy framework was not strong enough to ensure implementation throughout the entire sector.

The preferred low-carbon transition pathway is a pathway (or combination of complementary pathways) that addresses multiple environmental targets and contributes more to other development objectives relative to other pathways. A pathway focusing solely on addressing GHG emissions, therefore, is considered not sufficiently robust to be adopted within the sector on a wide scale, as it does not address other priorities within the sector. An effective low-carbon transition pathway would ideally maximise all kinds of synergies and minimise the amount of conflicts (or trade-offs).

1.6.2 TIS life cycle value chain: a cradle to grave analysis

To better understand the Dutch livestock sector it is not only relevant to know how the value chain (VC) for production, supply and end-use of animal protein (e.g. dairy and meat) looks like. It is also relevant to have an overview of the value chains to which it is linked. For example, the animal protein production value chain would not be possible without a functioning animal feed production value chain. In turn, the animal feed value chain is depending on the production and supply of fossil and organic fertilisers. A key by-product of the animal protein value chain is animal manure. As there is an industry working on processing animal manure in the Netherlands, this is also a relevant value chain to consider.

Figure 7 provides a structured overview of all five aforementioned value chains (VC) and their respective interlinkages. This overview resembles a partial material flow analysis of key resources (i.e. feed, fertilisers, manure, and energy) that are linked (as input or output) to the livestock sector that produces animal proteins (e.g. milk and meat). The figure shows a constellation of value chains that all are highly interdependent; it also shows that, to a certain extent, there is a 'circular interdependency' for the following value chains:

- Animal protein
- Manure Management
- Fertilisers
- Animal feed

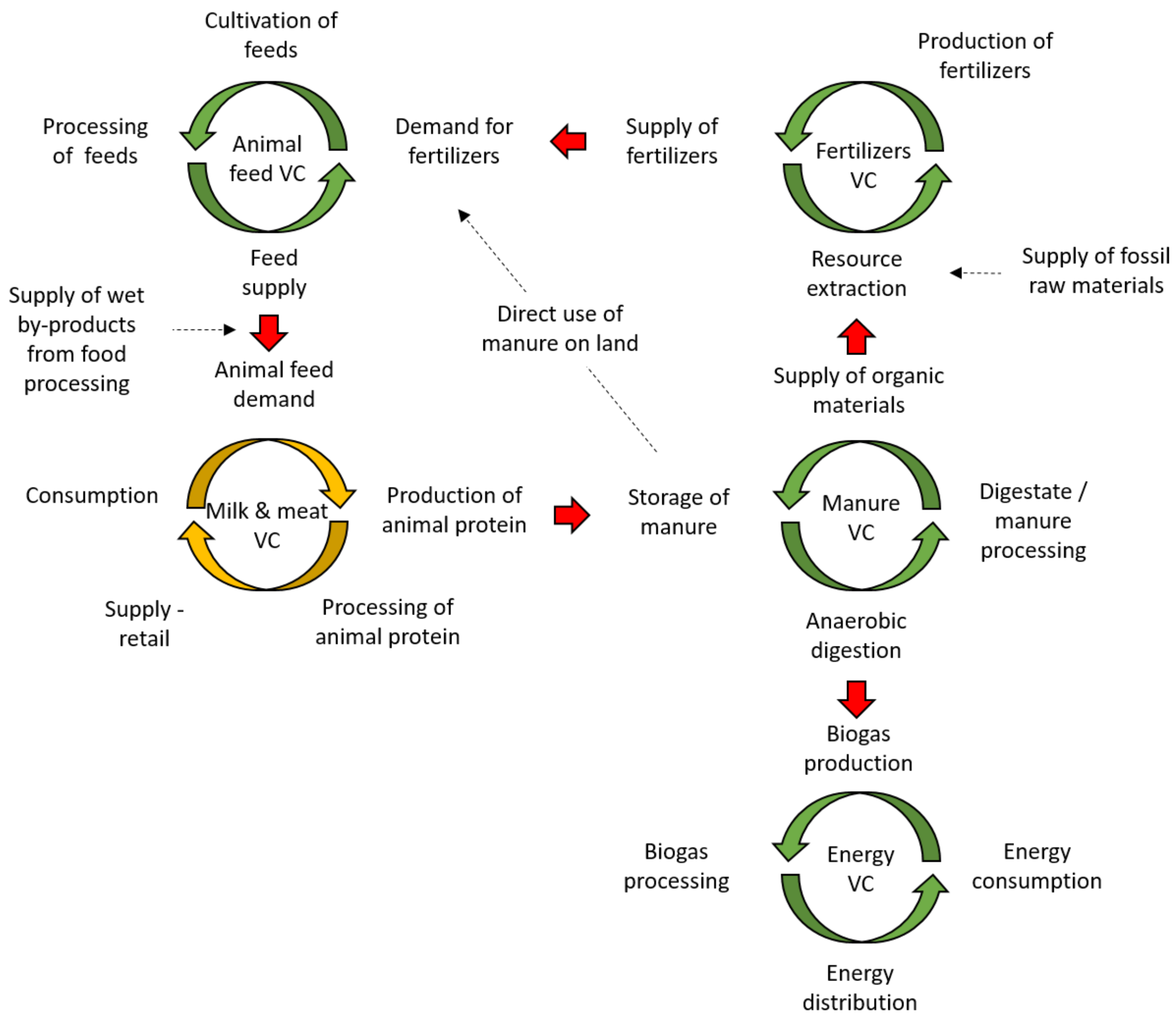

Figure 7: The Value Chain (VC) for animal protein (milk & meat) and its interlinkages with other relevant value chains for Animal feed, Fertilisers, Manure Management, and Energy

This circular interdependency can be illustrated by the following reasoning. 1) No animal protein without animal feed, 2) no animal feed without fertilisation, 3) no (organic) fertilisers without manure management, and 4) no animal protein without manure management. The first interdependency relates mainly to roughage feeds (and less to mixed feeds or imported feeds). Roughage feeds (like grasses and maize) comprise about 75% of the intake of dairy cows, which is generally produced locally. (Imported) mixed feeds (e.g. soy-based) and wet feeds (e.g. beet pulp, potato peelings) fill up the remaining 25% of the cows' diet (20% and 5% respectively).[22] Cultivation of roughage feeds requires considerable amounts of organic and fossil fertilisers. However, in order to grow food and feed, the Dutch agricultural sector predominantly makes use of animal manure for fertilisation (CLO, 2016c). In fact, in 2015, just under 5% of all phosphate (P2O5) needs of the agricultural sector were met with the help of fossil fertilisers; the rest was met with animal manure (or digestate). For nitrogen (N) needs, the agricultural sector obtains about 70% of all N for fertilisation from animal manure and the remaining 30% from fossil fertilisers. Hence the fourth interdependency: no animal feed without fertilisers.

This puts the energy (biogas) value chain in a different position. While manure digestion is dependent on the (excess) availability of manure, the interdependent value chains remain functional without this 'add-on value chain'. Manure digestion and biogas supply and use can therefore be seen as a non-essential 'add-on' to the livestock sector. This is also, more or less, how the livestock sector as well as policy makers have treated biogas production: as a stand-alone economic activity. With support schemes for biogas being far from ideal, and with:

- the food sector not willing/able to pay the feed sector,
- the feed sector not willing/able to pay the fertiliser sector,
- the fertiliser sector not willing/able to pay the manure sector, and
- the manure sector not willing/able to pay the food sector,

A premium price for more sustainable products and services, for example the costs for manure digestion (as a GHG mitigation option), currently cannot be recovered. This would not only count for biogas production, but also for all sorts of investments to reduce the environmental impact of the various value chains. Such environmental investments, made by an individual actor/company within a given value chain would need to be economically viable within the constellation of value chains. If other value chains do not accept (by not paying a viable price) such improvements, the individual actor will likely suffer the economic consequences. Therefore, a low-carbon transition within the livestock sector needs to take into account the interests and economic realities of individual actors/stakeholders.

Table 20 provides a non-exhaustive overview of key value chain stakeholders for all five aforementioned value chains. In addition to these key value chain stakeholders there is a broad range of other stakeholders that provide more supporting products, tasks, and services, such as financial, engineering, construction and transport services, etc. This category of stakeholders will be mapped in section 2.4 where appropriate.

[22] Pigs mainly are fed with mixed /concentrated feeds, and hence are dependent on the extent of local production of raw materials for mixed/concentrated feeds or imports.

Table 20: Key stakeholders in livestock, fertiliser, manure, animal feed and energy value chains

Value Chain	Key economic activities	Key stakeholders involved in value chain
Animal protein	Livestock breeding	Breeding farms
	Livestock farming	Pig and dairy farms
	Animal protein processing	Dairy cooperation, meat processors/slaughter houses
	Retail/supply of animal protein	Super markets, butcheries, etc.
	Consumption of animal protein	Households, restaurants
Animal feed	Cultivation of animal feed	Dairy farmers with own land, agricultural farms, importers
	Processing of feeds	Agricultural contractors, mixed/concentrated feed producers
	Supply of feeds	Wholesalers and retailers of feed products, or self-suppliers of feeds
Manure Management	Manure storage	Suppliers of livestock housing systems, pig/dairy farmers, manure transporters
	Anaerobic digestion	Suppliers of AD and gas treatment systems, pig/dairy farmers
	Digestate/manure processing	Suppliers of manure processing systems, pig/dairy farmers, third-party manure processors
	Supply of organic fertiliser	Wholesale trader, pig/dairy farmers
Fertilisers	Resource extraction	Fossil fuel producers/suppliers, traders in organic waste/manure,
	Production of fertilisers	Third party manure/digestate processors, fossil fertiliser producers
	Supply of fertilisers	Pig/dairy farmers, fossil fertiliser producers,
Energy	Biogas production	Suppliers of AD and gas treatment systems, pig/dairy farmers
	Biogas processing	Suppliers of gas upgrading and gas combustion systems, pig dairy farmers
	Energy distribution	Energy distribution companies
	Energy consumption	Households, industry, service sector, transport

1.6.3 Enabling environment: policy mixes in the socio-economic system

The key policies targeting the livestock sector, are environmental and agricultural policies. In addition to that there is a wide-range of socio-economic policies that for example affect the fiscal situation of livestock sector stakeholders, as well as the agreements with regards to health, safety and wages of employees. Table 21, provides a non-exhaustive overview of key EU level environmental policy frameworks and their associated national policies/strategies. All frameworks are targeting a specific environmental theme from water quality to climate change. All these policy frameworks play have an effect on any mitigation strategy undertaken in the Dutch livestock sector today and in the future.

Table 21: Key EU policy frameworks and national strategies/action plans relevant for a low-carbon transition in the livestock sector in the Netherlands

Environmental policy theme	Key EU Policy framework	General aim	National policies/strategies	Key elements (non-exhaustive)
Water quality	EU Nitrates Directive, 1991	Aims to protect water quality across Europe by preventing nitrates from agricultural sources polluting ground and surface waters and by promoting the use of good farming practices.	5th Action Plan Nitrates (2014-17)	- Manure treatment obligation (Mestverwerkingsplicht) - Pig and poultry production rights - Land-linked growth of the dairy sector (Grondgebonden groei melkveehouderij)[23] - Norms for using N and P & derogation - Phosphate production rights in dairy sector
Air quality	EU Air Quality Framework Directive (and following 'daughter directives'), 1996	Describes the basic principles as to how air quality should be assessed and managed in the Member States. It lists the pollutants for which air quality standards and objectives will be developed and specified in legislation.	National Cooperation Programme Air Quality (NSL), National Action Plan Air Quality (2015)	- Emission norms (on NO_2, PM, etc.) for geographic areas & derogation - Emission standards for vehicles - Regulation Ammonia and livestock (Rav)[24]

[23] https://www.rijksoverheid.nl/documenten/kamerstukken/2015/03/30/aanbiedingbrief-amvb-grondgebonden-groei-melkveehouderij
[24] http://wetten.overheid.nl/BWBR0013629/2016-10-01

Nature & biodiversity	EU Birds Directive (1979) and EU Habitat directive (1992)	Aims to protect the population and environment of (migratory) birds. Ensures the conservation of a wide range of rare, threatened or endemic animal and plant species.	Flora and fauna Act Nature protection Act Natura 2000 areas	- Programmatic Strategy Nitrogen Emissions (PAS), Annex 2 (specific measures for ammonia emissions from livestock)[25]
Renewable energy	EU Renewable Energy Directive, 2009	Promotes the production and use of energy from renewable sources	National Renewable Energy Action Plan/Energy Agreement (2013)	- Feed-in subsidy scheme (SDE+) - Energy Investment Deduction (EIA) - Pig & dairy sector: commits to 25% manure separation resulting in lower emissions
Climate change	EU Emissions Trading Scheme EU Effort Sharing Decision	Aims to reduce the impact of the EU's economy on climate change by establishing binding (national) targets for energy savings, renewable energy consumption as well as greenhouse gas emission reductions.	Covenant Clean & Efficient agro-sectors[26]	- Lowering use of fossil fertilisers - Implementing low-emission feeds in livestock
Agriculture	Common Agricultural Policy	Aims to regulate agricultural sector to produce food in a sustainable manner at competitive prices by gradually introducing market principles.	Rural Development Program 3 - 2014-20 (POP3)[27]	- Premium and/or quota systems for crops, meat, milk, etc. (abolition of milk quota system)
Circular Economy	Fertiliser Directive	Aims to enhance the efficient use of all kinds of fertilisers products used in agricultural activities, and to reduce the environmental impact of fertiliser use,	Fertiliser Act[28]	- Usage norms for fertilisers on arable land, - Regulations on storing, trading and treatment of manure, - Safety, quality and labelling standards for (organic) fertilisers,

[25] http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak/rav/pas-maatregelen/bijlage-2-regeling/
[26] https://www.rijksoverheid.nl/binaries/rijksoverheid/documenten/convenanten/2008/12/03/convenant-schone-en-zuinige-agrosectoren/convenant-schone-en-zuinige-agrosectoren.pdf
[27] http://www.rvo.nl/onderwerpen/agrarisch-ondernemen/gemeenschappelijk-landbouwbeleid/plattelandsontwikkeling
[28] http://wetten.overheid.nl/BWBR0019031/2016-01-01

1.6.4 Enabling environment: government institutions

Table 22 provides an (non-exhaustive) overview of the main public institutions that play a role with regards to the various EU policy frameworks that are linked to the environmental themes. Public institutions involved in the design, implementation and/or monitoring and evaluation of the various EU Directives include:

- Ministry of Economic Affairs, Agriculture and Innovation (EL&I),
- Ministry of Infrastructure and Environment (I&M)
- Dutch Agriculture – Horticulture Organisation (LTO)
- Netherlands Enterprise Agency (RVO),
- Netherlands Environment Assessment Agency (PBL),
- Wageningen University and Research (WUR)
- Netherlands Emission Authority (NEA)
- Union of Water Boards (UvW)
- InterProvincial Collaboration (IPO)
- Association of Dutch Municipalities (VNG)

Table 22: Major public institutions with appropriate (competent) authority and executive/implementing powers relevant for low-carbon transitions in the Dutch livestock sector

Key EU Policy framework	National policies/strategies	Major public institutions involved
EU Nitrates Directive, 1991	5th Action Plan Nitrates (2014-17)	Ministry of Economic Affairs, Agriculture and Innovation (EL&I) Land- en tuinbouworganisatie Nederland (LTO) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL) Wageningen University & Research (WUR) Vereniging Nederlandse Gemeenten (VNG) Unie van Waterschappen (UvW)
EU Air Quality Framework Directive (and following 'daughter directives'), 1996	National Cooperation Programme Air Quality (NSL), National Action Plan Air Quality (2015)	Ministry of Infrastructure and Environment (I&M) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL) Wageningen University & Research (WUR) Interprovinciaal Overleg (IPO) Vereniging Nederlandse Gemeenten (VNG)
EU Birds Directive (1979) and EU Habitat directive (1992)	Flora and fauna Act Nature protection Act Natura 2000 areas	Ministry of Infrastructure and Environment (I&M) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL) Wageningen University & Research (WUR) Interprovinciaal Overleg (IPO) Vereniging Nederlandse Gemeenten (VNG)
EU Renewable Energy Directive, 2009	National Renewable Energy Action Plan/Energy Agreement (2013)	Ministry of Economic Affairs, Agriculture and Innovation (EL&I) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL)
EU Emissions Trading Scheme EU Effort Sharing Decision	Covenant Clean & Efficient agro-sectors	Ministry of Infrastructure and Environment (I&M) Netherlands Emissions Authority (NEa) Netherlands Environment Assessment Agency (PBL) Interprovinciaal Overleg (IPO)
Common Agricultural Policy	Rural Development Program 3 - 2014-20 (POP3)	Ministry of Economic Affairs, Agriculture and Innovation (EL&I) Land- en tuinbouworganisatie Nederland (LTO) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL) Wageningen University & Research (WUR) Interprovinciaal Overleg (IPO) Vereniging Nederlandse Gemeenten (VNG)
Fertiliser Directive	Fertiliser Act	Ministry of Economic Affairs, Agriculture and Innovation (EL&I) Land- en tuinbouworganisatie Nederland (LTO) Netherlands Enterprise Agency (RVO) Netherlands Environment Assessment Agency (PBL) Wageningen University & Research (WUR)

1.7 The Innovation System map - Integrated Manure Management in the livestock sector

The key value chain stakeholder (of the Dutch livestock Innovation System Map), where the most influential environmental policies focus on is the livestock farmer. This stakeholder is targeted by a broad range of environmental policy frameworks on for example, Nitrates, Climate Change, Air Quality, Water Quality. It is this particular policy mix, and their associated targets that does not always provide an enabling environment for creating the desired low-carbon transition in this sector.

The broader environmental policy regime tries to trigger the livestock farmer to make investments in different clean technologies to lower emissions to air, water, soil and atmosphere. However, each individual policy framework is implemented in a specific timeline (policy cycle), and comes with a specific set of instruments that are focussed to meet that single environmental target. Overall, the 'timelines' of the mix of policy instruments do rarely overlap, which does lead to various sub-optimalities. Such sub-optimalities in investments arise when technologies / practices are not targeting several environmental impacts at the same time. For example, the air quality policy in the Netherlands, stimulates that air filtering systems in livestock stables are implemented. These ammonia strippers, are focussing on one single emissions category, while CH_4 emissions are not reduced. For reducing CH_4 emissions additional investments need to be made. In those cases, where the fragmented environmental policy approach leads to a series of (sub-optimal) non-integrated investments, the cost-effectiveness of the broader package of policy frameworks is likely to be lower. A more integrated (holistic) environmental policy approach is needed to minimise sub-optimalities. This does not only relate to the livestock farmer alone, but also to the (vested) interests and ambitions of other stakeholders in the Innovation System. In this market system, for example, the livestock farmer (i.e. the producer of animal protein) does not have a strong economic and bargaining position. This is because the market for processing, distribution and retail of animal proteins is highly concentrated. For example, in the Netherlands there are only a handful of large retail organisations (i.e. super market chains). These retail organisations have a strong influence on the prices for milk and meat that are paid to farmers.

Figure 8 provides an overview of the system map for the dairy sector. There are some clear distinctions with the pig meat sector, and hence the specific set of solutions and strategies towards a low-carbon future are likely to require some differentiation.

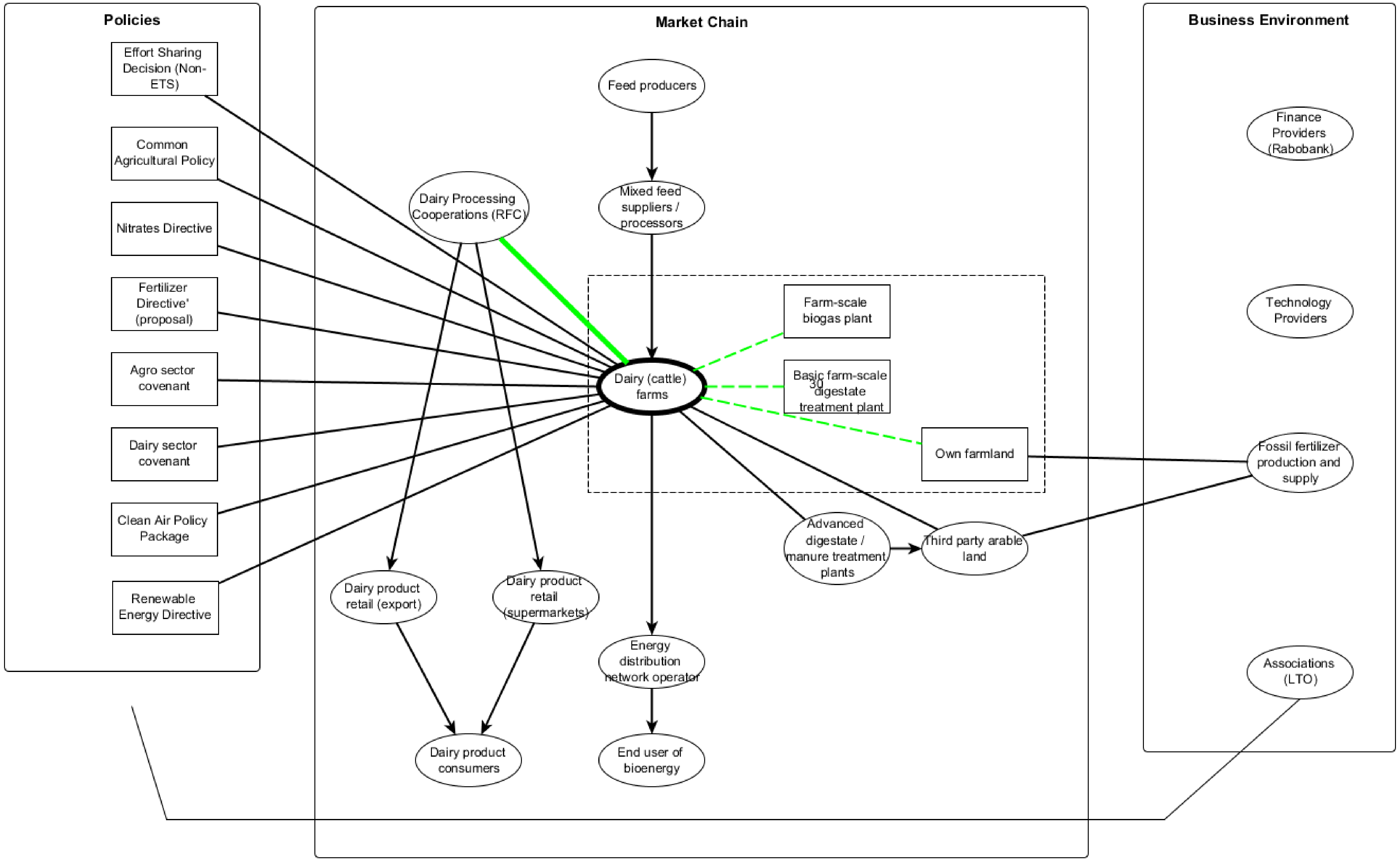

Figure 8: Innovation System map for the Dutch Dairy sector, including key stakeholders, and key EU policy frameworks

1.8 Stakeholder engagement - Integrated Manure Management in the livestock sector

Table 23 lists the stakeholders consulted for the integrated manure management in the livestock sector.

Table 23: Stakeholder Engagement

Type of stakeholder	Position in the organisation*	Economic sector**	Type of engagement***	Month and year contacted
1. Government	Programme Manager	Subnational	Informed / consulted	October
2. Industry (branch organisation)	Industry expert	Agro-livestock	Informed / consulted	November
3. Industry	Industry expert	Public-private / advisory	Informed / consulted	Frequent interactions

* Government (national/subnational), research/consultancy, business, other (specify)

** Energy, Industry, transport, environment, agriculture/forest, financial/trader, other (specify)

*** Interview, focus group, workshop, survey etc.

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