HyDelta

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Executive summary

In the Dutch Climate Agreement, renewable (and/or eventually low carbon) hydrogen is been considered essential to decarbonise the society. However, a support market mechanism will be required to compensate the higher costs of the production and/or consumption of this renewable type of energy compared to traditional fossil alternatives. In this paper, existing voluntary and mandatory schemes that are used to introduce renewable energy in the electricity, gas and transport fuel sector are assessed in order to address lessons and critical points of attention that should be taken into account in the way hydrogen could be supported and introduced effectively. Two voluntary schemes (the Dutch RES-E GO's by CertiQ and Dutch green gas GO's by Vertogas) and two mandatory schemes (the Dutch fuel blending obligation and the Norwegian-Swedish electricity quota) are assessed based on pre-determined characteristics in order to compare the reliability of these schemes, the tradability of certificates, the accumulation of support, the effects on deployment, the way the schemes are introduced and the perceived risks.

The generalized lessons and points of attention that can be concluded from the assessment are the following:

Guarantee of reliability

- The reliability of the scheme could become endangered when too large differences exist between the administrative and physical reality. Moreover, certification systems intend to see things black and white: 'green products' and 'not green products', while sometimes consumers perceive differences in the level in which several products are green. When the right information is provided at the certificates, these differences in 'greenness' will be priced in voluntary systems since these prices depend on the willingness-to-pay of a consumer. Due to the mandatory consumption of certificates in the mandatory systems, it is experienced less likely that voluntary higher prices will be paid for certain products if cheaper options are available. When an undesirable amount of a typical technology would be established, we have seen in the Dutch fuel blending scheme that sub-quota targets can be used to deal with 'differences in greenness' between products.
- The more diverse the use applications of certain resources are and the more complex the value chains of those resources, the more complex it will be to prevent the system from fraud or outcompeting the use of the same resources in other sectors. Such issues are especially seen with biomass in the existing schemes, but similar issues could be expected with other resources that have one or multiple of these characteristics as well (e.g. scarce renewable electricity that is desired to be used in multiple sectors for decarbonization).

Tradability of certificates

- When schemes allow international trade, it should be considered that differences in the existence of the stimulated technologies (e.g. a lot of renewable electricity available in Norway) and the way technologies are stimulated among countries (e.g. countries that stimulate biomethane use buy certificates and countries that stimulate biomethane production export certificates) will have large impact on the import and export of certificates.
- It should be considered that the combination of production subsidies and voluntary GO schemes could lead to 'leakage' of national support financed by taxes that are used for carbon reductions claimed by other countries, when large shares of certificates are exported. The Norwegian-Swedish electricity quota is an example how the costs for support can be distributed proportionally between end-users.
- Generally, the more uncertainty is perceived in business cases or the commodity and certificate markets, the more likely it is that market players will prefer long term agreements

for the purchase of renewable energy. This is especially seen in renewable electricity markets where stable fossil generation will be replaced by intermittent solar PV and wind generation.

Allowance in cumulation of support schemes

- In the voluntary schemes, the certificate revenues and subsidies could be accumulated. Since two years ago, only revenues for the wind and solar PV GO's are taken into account in determining the level of SDE++ subsidy.
- In the mandatory schemes, it was seen that production batches with subsidized 'resources' or 'inputs' could not be used to comply to the Dutch fuel blending quota. In the Norwegian-Swedish electricity quota scheme, it was seen that with a clear distinction in purpose between 'tracking' and 'support' certificates, revenues for both Quota Certificates and Guarantees of Origin could be obtained.

Effects on investments and deployment

- In both assessed voluntary schemes, the certificate prices have a small contribution in closing the unprofitable gap of the renewable energy production technologies. In these cases, the subsidy was the largest contributor to close the unprofitable gap of the business case. While in both mandatory schemes, the certificate prices had a large impact in closing the business case of additional renewable technologies.
- The SDE++ is effective in deployment for technologies that decrease carbon emissions against relatively low costs, as the subsidy is only used for the most cost effective carbon reduction technologies. For technologies, such as biomethane, which are considered essential but are relatively high in costs per reduced ton of CO_2, the deployment will be limited as long as more cost effective technologies are available. For decarbonization of specific sectors, both mandatory schemes that were assessed reached their goal of renewable energy use.

Introduction of schemes

- All four assessed schemes are legally embedded by the national governments. The voluntary schemes were implemented by companies 100% owned by the electricity and gas TSO's and the mandatory schemes were implemented by governmental authorities. Also, the voluntary systems use advising councils consisting of producers and consumers while the mandatory systems do not use such formalized councils to obtain input from the market parties.
- In three of the four assessed schemes, international trade of certificates has been developed at a later stage to increase the market liquidity and cost-effectiveness deployment of renewable energy capacities.

Perceived risks

- One of the major risks perceived in support schemes is the risk that subsidies paid by national taxes will leak away towards other countries. The assessed mandatory schemes had more clear geographical boundaries and did not include different national support schemes connected via international exchange of certificates. Moreover, the leakage risks are lower in the mandatory schemes, as 'the user pays'-principle was used.
- Especially for the mandatory schemes, the speed of introduction is a very important factor to consider. In both assessed schemes there were no reports that the level of the target rose faster than supply could be developed. Thereby, buy-out prices were used in both schemes.

Based on the comparisons between the assessed schemes, it could be concluded that the voluntary schemes assessed mainly focus on the deployment of the most cost effective carbon reduction technologies, while the mandatory schemes give more guidance and security that certain types of end-use applications or sectors could become decarbonized. The voluntary schemes have uncertainty in the actual deployment (depending on how much deployment can be supported with the determined budget), while the mandatory schemes have more uncertainty in the costs calculated towards the end-users. The advantage of ‘the user pays’-principle via the same mechanism, is that subsidies cannot ‘leak away’ due to differences in national policies. However, more careful attention should be paid to the introduction and the perceived reliability of the scheme.

With regards to the implementation of a hydrogen admixing scheme, all lessons concluded above are essential to take into account with regards to considerations of the systems design and desired purposes. Obviously, although analysed carefully, the experiences based on assessed energy admixing regimes are not fully interchangeable and comparable with the situation and purposes that a hydrogen admixing policy could have. The assessment is a case study, and the case of hydrogen will differ with its own characteristics. However, the generalized lessons can be taken as critical points of attention that should be used and analysed further when it comes to the question of how renewable hydrogen can be introduced to decarbonize the energy system.

Samenvatting

In het Nederlandse Klimaat Akkoord wordt de noodzaak van gebruik van hernieuwbare (en/of eventueel CO_2-neutrale) waterstof beschreven om naar een koolstofvrije samenleving te gaan. Echter zal er een marktmechanisme nodig zijn om het gat in kosten voor productie en/of consumptie van deze hernieuwbare energievorm te dichten, dat ontstaat door de lagere kosten van traditionele, fossiele alternatieven. In dit paper zijn verschillende vrijwillige en verplichte mechanismen geanalyseerd die zijn gebruikt om hernieuwbare energie te introduceren in de elektriciteit, gas en brandstof sectoren, om vanuit deze ervaringen generieke lessen te trekken die in acht genomen zullen moeten worden voor een effectieve introductie van waterstof. Hiervoor zijn de werking en ervaringen van twee vrijwillige regelingen (de Nederlandse hernieuwbare elektriciteit GvO's van CertiQ en de groen gas GvO's van Vertogas) en twee verplichte regelingen (de Nederlandse bijmengverplichting voor brandstoffen en het Noors-Zweedse elektriciteitsquotum) beschreven gebaseerd op vooraf bepaalde karakteristieken. Vervolgens zijn de regelingen met elkaar vergeleken op basis van de betrouwbaarheid, de verhandelbaarheid van certificaten, in hoeverre opeenstapeling van support wordt geaccepteerd, het effect op de realisatie en gebruik van hernieuwbare energie, de manier hoe de regelingen zijn geïntroduceerd en de voorziene risico's.

Op basis hiervan zijn de volgende generieke lessen en aandachtspunten geconcludeerd:

<u>Garantie van betrouwbaarheid</u>

- Er is gezien dat de betrouwbaarheid van de regeling in het geding kan komen wanneer te grote verschillen ontstaan tussen administratieve claims en de fysieke werkelijkheid. Daarbovenop lijken de certificatensystemen vaak zwart-wit te suggereren: 'groene producten' en 'niet groene producten', terwijl er in de realiteit verschillende gradaties in 'groenheid' zijn of worden verondersteld door eindgebruikers. Wanneer de juiste informatie wordt gegeven via de certificaten is gezien in de vrijwillige systemen dat dit verschil in veronderstelde 'groenheid' terugkomt in de prijzen die betaald worden voor verschillende typen certificaten. De onvrijwillige basis van de verplichte systemen zorgt ervoor dat het minder waarschijnlijk is dat er hogere prijzen worden betaald voor bepaalde producten als er een goedkopere optie beschikbaar is. In de Nederlandse bijmengverplichting voor brandstoffen is gezien dat sub-quota doelen gesteld kunnen worden om onderscheid te maken tussen dit 'verschil in groenheid'.
- Hoe meer divers de eindgebruik mogelijkheden van bepaalde grondstoffen en des te complexer de ketens vanwaar deze worden aangeleverd, hoe moeilijker het wordt om fraude en ongewenste competitie tussen grondstoffen te voorkomen. Deze problemen zijn met name ervaren met biomassa in de huidige regelingen, maar kunnen ook verwacht worden met andere grondstoffen die een of meerdere van deze karakteristieken hebben (bijvoorbeeld hernieuwbare elektriciteit waarvan gebruik wordt voorzien in verschillende sectoren om uitstoot terug te brengen).

<u>De verhandelbaarheid van certificaten</u>

- Wanneer internationale handel tussen certificaten geoorloofd is, zullen verschillen tussen landen, zoals bestaande inzet van gestimuleerde technologieën (zoals hernieuwbare elektriciteit in Noorwegen destijds) en de verschillen van ondersteuningsmaatregelen tussen landen (zoals verschillen tussen landen in het stimuleren van productie van bio-methaan en consumptie van bio-methaan), in acht genomen moeten worden omdat dit grote impact zal hebben op de import en export stromen van certificaten.

- De combinatie van productie subsidies en vrijwillige GvO regelingen kan leiden tot het 'lekken' van nationale support betaald met belastinggelden naar het buitenland. Dit gebeurd wanneer buitenlandse eindgebruikers de certificaten opkopen en hiermee de CO_2 reductie kunnen claimen. Het Noors-Zweedse elektriciteitsquotum is een voorbeeld hoe de kosten van support naar rato kunnen worden verdeeld over alle eindgebruikers.
- Over het algemeen wordt gezien dat de veronderstelde onzekerheid in de businesscases en gerelateerde markten bepaald of marktspelers de voorkeur hebben voor lange termijn overeenkomsten voor de inkoop van hernieuwbare energie. Dit wordt bijvoorbeeld gezien in de elektriciteitsmarkten waar stabiel-producerende fossiele bronnen vervangen worden door fluctuerend producerende zon en wind installaties.

Acceptatie van cumulatie in support

- In de geanalyseerde vrijwillige regelingen kunnen de opbrengsten van certificaten bij de ontvangen subsidiegelden opgestapeld worden. Wel kan er bij het aanvraagproces voor gekozen om de certificaatopbrengsten van het subsidiebedrag af te trekken, om daarmee een betere positie te verkrijgen in het aanvraagproces. Sinds een aantal jaar worden de opbrengsten van wind en zon GvO's wel meegenomen in het basisbedrag voor de SDE++ subsidie.
- In de Nederlandse bijmengverplichting voor brandstoffen is het niet mogelijk om gesubsidieerde 'inputs', zoals gesubsidieerde groen gas productie batches, te gebruiken in brandstoffen die meetellen voor het quotum. Het Noors-Zweeds elektriciteitsquotum maakt een strikt onderscheid tussen 'quota certificaten' en 'volg certificaten', waarbij voor beide certificaten opbrengsten kunnen worden gegenereerd.

Effecten op investeringen en gebruik

- In beide beoordeelde vrijwillige regelingen hadden de certificaatprijzen een geringe bijdrage in het dekken van de onrendabele top van hernieuwbare energie productie technologieën. In deze gevallen was de subsidie met name verantwoordelijk voor het mogelijk maken van de investering. Daarentegen waren de certificaatprijzen in de verplichte regelingen de reden dat de onrendabele top van de additionele hernieuwbare technologieën gedicht kon worden.
- De SDE++ is effectief in het bevorderen van inzet van technologieën die CO_2 besparingen tegen relatief lage kosten kunnen bewerkstelligen, gezien het gelimiteerde beschikbare budget dat gebruikt wordt voor de meest kosteneffectieve besparingstechnieken. Voor technologieën die wel als essentieel worden gezien voor CO_2 neutraliteit maar relatief hoge kosten per vermeden ton CO_2 met zich meebrengen, zoals bijvoorbeeld bio-methaan productie, wordt de inzet maar erg beperkt gestimuleerd zolang er meer kosteneffectieve technologieën voor andere toepassingen beschikbaar zijn. Als het gaat om het verduurzamen van specifieke sectoren, waren beide verplichte regelingen succesvol in het behalen van hun doelen.

Introductie van de regelingen

- Alle vier geanalyseerde regelingen zijn regulatief ingebed door de nationale overheden. De vrijwillige certificaten systemen zijn geïmplementeerd door bedrijven die voor 100% eigendom zijn van TSO's en de verplichte certificaten systemen zijn geïmplementeerd door overheidsinstanties. Daarnaast gebruiken de vrijwillige systemen adviesraden bestaand uit producenten en consumenten terwijl de verplichte systemen geen formele raden gebruiken om directe input vanuit marktpartijen te verkrijgen.
- In drie van de vier regelingen is internationale handel van certificaten op een later moment geïntroduceerd om de markt liquiditeit en kosten effectiviteit van de inzet van de hernieuwbare energie capaciteit te vergroten.

Verwachtte risico's

- Een van de meest overwogen risico's van support mechanismes, is dat deze regelingen betaald door nationale belastingen weglekken naar andere landen. Doordat de geanalyseerde verplichte regelingen een scherpe geografische afbakening en geen verschillen in additionele support mechanismes tussen de landen hadden, werden hier geen risico's tot weglekken gezien. Daarbovenop wordt dit risico verkleint door het 'de gebruiker betaald'-principe.
- Waakzaamheid is erg belangrijk bij de snelheid van de introductie van met name de verplichtende regelingen. In beide geanalyseerde regelingen waren geen indicaties dat de verplichting sneller steeg dan dat productie kon worden ontwikkeld. Daarbij konden eventueel een uitkoopsommen betaald worden als niet aan de verplichting kon worden voldaan.

Gebaseerd op de vergelijking tussen de verschillende regelingen kan worden geconcludeerd worden dat de vrijwillige regelingen met name gefocust zijn op het reduceren van zoveel mogelijk uitstoot gegeven het beschikbare budget, waar de verplichtende regelingen meer richting en zekerheid geven dat verschillende typen eindgebruik hun uitstoot gaan reduceren. De vrijwillige systemen hebben daarbij meer onzekerheid in de hoeveelheid hernieuwbare energie dat ingezet kan worden (gegeven het beschikbare budget), terwijl de onzekerheid bij de verplichtende regelingen met name zit in de kosten doorgerekend aan eindgebruikers. Het voordeel van het 'de gebruiker betaald'-principe volgens hetzelfde mechanisme, is dat subsidies niet kunnen weglekken door verschillen in nationale regelgeving. Echter, zijn in dat geval de introductie van het systeem en de betrouwbaarheid belangrijke punten van aandacht.

Alle bovenstaande punten zijn essentieel om meegenomen en -gewogen te worden als het gaat om het ontwerp van regelingen die het gebruik van waterstof als hernieuwbare energiedrager moeten stimuleren. Natuurlijk zijn de ervaringen van de vergeleken regelingen niet 1-op-1 inwisselbaar en vergelijkbaar met de met de situatie en doelen die worden beoogd met waterstof. Net zoals de meegenomen cases en hun karakteristieken nauwkeurig geanalyseerd zijn, heeft de situatie van waterstof ook haar unieke karakteristieken. Desalniettemin kunnen de generiek beschreven lessen als kritieke punten beschouwd worden die overwogen moeten worden als het gaat om de vraag hoe hernieuwbare waterstof geïntroduceerd kan worden om het energie systeem te verduurzamen.

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Abbreviations

AIB	*Association of Issuing Bodies*
Bio-ETBE	*Bio-Ethyl-Tertiary-Butyl-Ether*
EECS	*European Energy Certificate System*
(EU)ETS	*(European) Emission Trading Scheme*
CEN	*European Committee for Standardisation*
CHP	*Combined Heat and Power*
CNG	*Compressed Natural Gas*
FAEE	*Fatty Acid Ethyl Ester*
FAME	*Fatty Acid Methyl Ester*
GO(s)	*Guarantee(s) of Origin*
HBE(s)	*Hernieuwbare brandstofeenheden*. 'Renewable Fuel Units'
HEV	*Hernieuwbare Energie voor Vervoer.* 'Renewable Fuel Obligation'
HVO	*Hydrotreated Vegetable Oil*
IPCC	*International Panel on Climate Change*
ISCC	*International Sustainability and Carbon Certification*
LNG	*Liquified Natural Gas*
LPG	*Liquified Petroleum Gas*
MEP	*Milieukwaliteit Elektriciteitsproductie.* 'Environmental Quality of Electricity Production'
NEa	*Nederlandse Emissieautoriteit.* 'Dutch Emission Authority'
NTA	*Nederlandse Technische Afspraak.* 'Dutch Technical Agreement'
NVE	*Noregs Vassdrags- og Energidirektorat, 'Norwegian Water Resources and Energy Directorate'*
PoS	*Proof of Sustainability*
PPA	*Power Purchase Agreement*
RED	*Renewable Energy Directive*
REV	*Register Energie voor Vervoer*. 'Energy for Transport Registry'
RVO	*Rijksdienst voor Ondernemend Nederland.* 'Netherlands Enterprise Agency'
ERGaR	*European Renewable Gas Registry*
SDE(++)	*Stimulatie Duurzame Energie.* 'Stimulation of Renewable Energie'
SER	*Sociaal Economische Raad* 'Social Economic Council'
STEMFS	*Statens Energimyndighets Författningssamling,* 'Swedish Energy Agency's Constitution'
TSO	*Transmission System Operator*
VRE	*Variable Renewable Energy*

Definitions

Lte	*Levering tot eindverbruik.* 'Taxed delivery for final consumption' - The total amount of petrol and diesel (including their bio-components) that a company has delivered to transport destinations that are subject to an obligation in the Netherlands.
UtV	*Uitslag tot vervoersverbruik*. 'Taxed delivery for transport use' - The total amount of fuels that a company has delivered to transport destinations subject to an obligation in the Netherlands.

1. Introduction

It is calculated by multiple energy system scenario's that renewable and eventually carbon neutral hydrogen will be required in order to achieve a fully decarbonized Dutch society. Currently, no significant production capacities of renewable or low carbon hydrogen are existing in the Netherlands. In the Dutch Climate agreement that was published in 2019, it is stated that 3-4 GW of electrolysis capacity should be established in the Netherlands in 2030, in order to achieve the overall carbon reduction target of 49% in 2030 [1]. Therefore, renewable (and eventually low carbon) hydrogen should be introduced into the Dutch gas flows, and some market mechanisms should be required to distinguish and support the renewable hydrogen that would be admixed into the other gas flows (e.g. fossil hydrogen or natural gas).

Similar market mechanisms are seen with regards to the introduction of renewable electricity, biomethane and renewable fuels. Some of those market mechanisms had a voluntary character, which means that consumers are free to decide if they want to pay a premium for renewable energy. Other market mechanisms are mandating consumers to pay a premium for a pre-defined share of their consumption. It is expected that lessons can be learned from the experiences from the introduction of these other types of renewable energy, and the market mechanisms that were used. Therefore, this paper will execute an assessment of four selected schemes, based on pre-defined characteristics. These cases will be analysed and compared in order to identify lessons and key points of attention that can be taken into account for the development of market mechanisms in order to introduce renewable hydrogen into the Dutch energy system.

In the next sections, the selection of schemes and the characteristics that will be used in the assessment are introduced. Thereafter, each scheme will be described and analysed based on the pre-determined characteristics. Finally, a comparison of the schemes will be done and general conclusions are being made.

1.1 Selection of schemes for assessment

Four schemes are being selected to be assessed: renewable electricity in the Netherlands, green gas (i.e. biomethane) in the Netherlands, the Dutch fuel blending quota and the Norwegian-Swedish electricity quota. This selection has been based on multiple criteria. The first criteria is the division between voluntary and mandatory schemes, of both two schemes are selected. The reason to include both types of schemes is to compare their differences, advantages and disadvantages. Secondly, there is chosen to assess multiple energy sectors, such as the electricity, gas and fuel sector. The electricity sector has already introduced support mechanisms quite long ago and technologies are relatively far in cost competitiveness against fossil technologies and the gas and fuel markets are interesting as these technologies may be further away from cost competitiveness and hydrogen is foreseen to be play a role in both markets. Thirdly, mostly schemes located in the Netherlands are selected in the assessment. The paper focusses on the introduction of hydrogen in the Netherlands, and therefore it is relevant to compare schemes in the same legislative environment and national characteristics (e.g. geography, population, industry etc.). The Norwegian-Swedish electricity quota is selected to include another mandatory scheme in the assessment. The scheme is applicable for its shared market among multiple countries and the fact that a lot of information could be found about the developments and effects of the scheme.

Table 1: Overview of selected schemes for the assessment

	Voluntary schemes		Mandatory (quota) schemes	
Scheme	RES-E GO's by CertiQ	Green gas GO's by Vertogas	Dutch fuel blending obligation	Norwegian-Swedish electricity quota
Sector	Electricity	Gas	Transport fuels	Electricity
Country	Netherlands	Netherlands	Netherlands	Norway and Sweden

1.2 Selection of assessment characteristics

The selected schemes will be assessed in a semi-structured way in order to make comparisons possible. Therefore, similar characteristics are selected that are considered as relevant to obtain information about the introduction and deployment of renewable energy use in those sectors. First of all, for each scheme the general characteristics and purposes of the schemes are described. Secondly, legislative characteristics are assessed, such as the combination with other support schemes, the international environment and the reliability of the scheme are investigated. These factors could heavily impact the way renewable capacity and consumption are developed. The same applies for the economic characteristics, such as the prices paid for the certificates, the impact these additional revenues have on closing the unprofitable gap in business cases, how these contributed to the actual deployment of the renewable energies and how the systems are financed. Finally, at the end the purpose of the schemes is to reduce the negative impact of the energy sectors on climate change. Therefore, it is assessed to what degree it could be proven that the systems reduce emissions in reality and administratively. Thereby, it is assessed what (negative) environmental side-effects are experienced in the existing schemes. In Table 2, an overview of the characteristics used for each scheme in the assessment is given.

Table 2: Overview of selected characteristics used in the assessment

Voluntary schemes	**Mandatory (quota) schemes**
General and design characteristics	
• Aim of the scheme • Description scheme • How is it introduced	• Aim of the scheme • Description scheme • How is it introduced • Obligated market parties (and distinction between sectors/parties) • Accepted sources and sub-targets
Legislative characteristics	
• Combination with regulations/support schemes • Reliability of the scheme • Interaction with international arena	• Combination with other regulations/support • Reliability of the scheme • Interaction with international arena

Economic characteristics	

• Price effects in the schemes
  ○ Price volatility
  ○ Price transparency
  ○ Price level
• Effect of scheme on deployment/investment
  ○ Deployment increase
  ○ Effect on business case
	• Price effects in the schemes
	  ○ Price volatility
	  ○ Price transparency
	  ○ Price level
	  ○ Minimum/maximum price levels
	• Effect of the scheme on deployment/investment
	  ○ Deployment increase
	  ○ Effect on business case

Environmental characteristics	
• Availability of resources • Perceived sustainability & environmental impacts • Claims for CO_2 reductions	• Availability of resources • Perceived sustainability & environmental impact • Claims for CO_2 reductions

2. Dutch green electricity admixing

2.1 General and design characteristics

2.1.1 Aims and purposes of the scheme

The main aim of the Guarantees of Origin for electricity are to provide reliable information about the origin of generated energy in order to increase the traceability of energy and improvement of energy markets [2]. Thereby, information and the certificates themselves are used for the following purposes [3]:

- The certificates can be sold by producers to receive a premium on their renewable production, and consumers or energy suppliers who are willing to pay extra for the proof that their consumed electricity is produced by renewable sources can purchase and cancel these certificates.
- The certificates are used to obtain the SDE++ subsidies (and the previous SDE(+) and MEP subsidies).
- The certificates are used to comply to the Electricity Flow Labeling ('Stroometikettering') regulations that were applied in 2005. In this regulation, producers, supplier and traders are obligated to show the mix of sources that were used of the produced, supplied or traded electricity. Shares of renewable electricity only count when GOs are cancelled.
- Data from the scheme are one of the instruments used by the Dutch center for publications about renewable energy statistics and progression in renewable energy targets in the Netherlands.

2.1.2 Design of the scheme

CertiQ issues different types of GOs:

- GOs for electricity from renewable sources (solar, wind, water, biomass);
- GOs for electricity from fossil sources;
- GOs for renewable heat (biomass, solar thermal, geothermal);
- GOs for combined electricity and heat from renewable sources (biomass).

As this part of the assessment focuses on admixing of renewable electricity, the main focus will be on the GOs for electricity from renewable sources and their role to introduce renewable electricity into the Dutch electricity sector. This GO scheme works as follows. Producers which meet the requirements can register themselves at CertiQ. Thereafter, CertiQ receives (mostly on a monthly basis) data from the grid operator or measurement company that includes how much electricity is produced by the registered installations. When the data is approved by CertiQ, the GOs are issued to the CertiQ account of the producer. Certificates can be traded between other account holders, until an account holder decides to cancel the certificate in order to 'green' a share of its electricity consumption (see Figure 1).

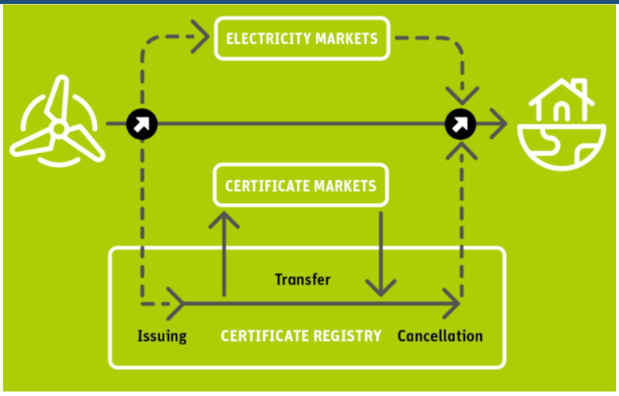


Figure 1: Schematic representation of a certification system [4]

According to EU regulations in the RED II (2018/2001/EC), a GO represents 1 MWh of electricity and expires one year after its production date. Furthermore, standardization criteria of electricity certificates throughout Europe are provided by the CEN-EN 16325. As there are these EU guidelines for GOs and an European Energy Certifcate System (EECS) is created by the Association of Issuing Bodies (AIB)[1], electricity GO's from different countries can be traded and exchanged internationally throughout Europe.

CertiQ has received the legal authority from the Dutch state of being the only party that is able to issue earlier mentioned GOs in the Netherlands. Traders pay an annual fee and transaction costs that are determined by the Dutch minister of Economic Affairs, in order to cover the costs of operating the scheme.

2.1.3 Introduction of the scheme

Following the Electricity Law that was introduced in 1998, the government introduced a certificate system in 2001 to facilitate the trade in and supply of "green" electricity as the market for sustainable electricity liberalized.

The system is managed by a company called 'Groencertificatenbeheer', which was founded in 2001. In 2003, the name was changed to CertiQ, partly to reflect an expansion of the company's activities. TenneT TSO B.V. - CertiQ's parent company - owned all of the company's shares. TenneT was officially designated as the issuing body for guarantees of origin by the Ministry of Economic Affairs in December 2003. CertiQ is also the Netherlands' issuing body for the Renewable Energy Certificate System (RECS), a commercial European certificate system initiated by a number of market participants [5].

The introduction of the certificate system is closely linked to developments in the energy sector, particularly the importance placed on generating sustainable electricity in 1997 by governments around the world. In the Japanese city of Kyoto, the major industrialised nations agreed to reduce carbon dioxide (CO_2) and other greenhouse gas emissions (through the 'Kyoto Protocol'). Between 2008 and 2012, the goal was to reduce emissions by 5% on average compared to 1990 levels [5].

CertiQ's Guarantees of Origin are the only proof allowed in the Netherlands that electricity was generated in a sustainable manner. Guarantees of Origin are used by the Office of Energy Regulation (DTe) to check electricity labels, contributing to the market for sustainable electricity's transparency and verifiability.

[1] The AIB is an umbrella organization of multiple Issuing bodies of RES-E GOs in Europe

Another goal of the Guarantees of Origin is to make the market for renewable energy more accessible. The certificates increase market liquidity because they can be traded separately from the electricity contracts.

Finally, based on the aforementioned Guarantees of Origin and CHP certificates, CertiQ's sister company EnerQ distributed MEP[2] grants. Electricity generated from sustainable sources such as wind, biomass, solar energy, and hydropower, as well as combined heat and power plants, could be subsidized under the MEP scheme [5].

Legal status

CertiQ is a 100% subsidiary of the electricity transmission company Tennet TSO B.V. The Dutch Minister of Economics, Agriculture and Innovation has designated TenneT as the only company in the Netherlands that is entitled to issue Guarantees of Origin and Disclosure Certificates. CertiQ has been appointed to perform these legal tasks on behalf of TenneT.

Cross border cooperation

CertiQ is a member of the Association of Issuing Bodies (AIB)[3], an international partnership of European Guarantee of Origin issuing bodies. The AIB strives to standardise certification systems to facilitate trade in sustainable as well as other forms of energy.

Participants' council

The CertiQ Participants' Council represents the interests of the participants in the certification system. This enables CertiQ to adjust policies and annual plans to meet needs. The Council, which includes producers, traders and representatives of some large energy suppliers, currently consists of the following members:

- Climex
- Engie Energie Nederland N.V.
- Holland Solar
- Greenchoice
- Vattenfall
- PZEM
- AFS
- Statkraft
- Attero
- Energie Samen (NWEA)

2.2 Legislative characteristics

2.2.1 Combination with other regulations and support schemes

It should be considered that the GOs were not the primary tool to support renewable electricity generation in the Netherlands, those were the MEP (2003-2006) and the SDE (2008-current). However, the GO system of CertiQ is used to check if installations meet the requirements to obtain those subsidies and also the production volumes that are registered are used by the RVO to check how much subsidy should be provided to the producers [3]. Therefore, the information provided by the GO scheme and the information required for subsidies are going hand in hand.

[2] The *"Ministeriële regeling milieukwaliteit elektriciteitsproductie"* or MEP regulation for short, was a ministerial regulation of the Dutch Ministry of Economic Affairs. The scheme was introduced on 1 July 2003 and was discontinued in 2006. The MEP replaced the Regulating energy tax and was succeeded in 2008 by the Incentive Scheme for Sustainable Energy Production.

[3] https://www.aib-net.org/

2.2.2 International interactions

As stated, CertiQ is member of the AIB which created the overarching EECS to exchange electricity GOs between the national issuing bodies. International exchange of electricity GOs is a common practice. Figure 2 shows the import and export of electricity GOs in the Netherlands. It shows that a large share of the cancelled certificates are imported from other countries, and three times more certificates are imported each year than issued in the Netherlands itself [6]. From 2012 until 2018, the share of certificates cancelled that originated from other countries increased every year [7]. In the last two years this trend stopped and the share of Dutch certificates increased. On the other hand, also certificates are exported to other countries. A very small share of production is used by producers itself to green their own electricity consumption.

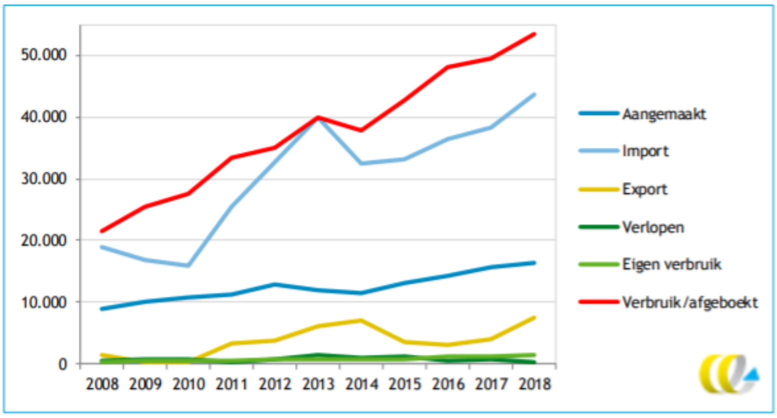


Figure 2: Issuance, cancellation, and international exchange of electricity GOs in the Netherlands (in GWh) [6]

In 2012, a large share (69%) of electricity GOs was purchased from Norway produced with hydropower. In Norway a lot of 'green' hydro-electric electricity generation capacity existed already and therefore there was less demand for certificates to proof the 'greenness' of electricity consumption which led to very low GO prices. Since 2015, more and more certificates are imported from other countries and besides hydro GOs also more wind GOs are imported from countries as Spain, Italy, France, Denmark and Sweden [7]. The reason for the large share of import is the difference in price between Dutch and foreign GOs [6], this will be discussed further in the economic section.

Despite these differences in prices, also smaller shares of GOs are exported. In the period of 2018-2020, most exported certificates (from biomass and wind) were traded to Norway, Germany and Belgium [7].

2.2.3 Reliability of the scheme

Credibility of the GO scheme

The major credibility issues of the electricity GO system were addressed in 2012 by research of SOMO that was commissioned by the Dutch Consumers Association and Greenpeace [8] and a lot of other news articles. Due to the high levels of imported GOs from Norwegian hydropower, a lot of Dutch electricity suppliers advertised their green energy contracts while actually barely renewable electricity was produced in the Netherlands at all. Therefore, the green power offerings were labelled by some journalists as 'cheating power'. The main criticism on the certification scheme itself could be summarized by the following points:

- Due to the large existing (international) supply of green (hydro)power and low demand for the certificates, market demand was already fulfilled by existing renewable electricity production instead of creating a market incentive to stimulate investments in additional renewable energy [9];

- The large difference in the 'administrative' claims and the 'physical' reality of the Dutch electricity consumption [10];
- The potential risk on double counting, when prosumers in Mediterranean countries claim to be green due to the solar panels on their roofs, but meanwhile their energy suppliers sell (a share of) their GOs to Dutch consumers [10];
- The purchase of imported GOs does not contribute to the Dutch national renewable energy production targets, while the misconception exists that this is the case when consumers purchase green power [10].

Fraud

While there were some fraud issues with the previous Dutch 'green certificates' system, no large fraud issues were faced in the CertiQ GO scheme. However, in 2019 indications were found that the CertiQ scheme could be used by criminal organisations to commit tax fraud [11]. Previously, also ETS certificates were abused for similar purposes.

Transmission losses

Another issue that electricity GO schemes faces are that transportation losses of electricity are not considered, since same volumes of certificates issued to producers can be used by consumers. This means that administratively more green electricity can be consumed than actually arrives physically at the consumers. Although differences are limited currently, the longer the distances that electricity is transported due to internationalisation of the electricity markets and introduction of offshore windfarms, the larger these differences might become in the future.

2.3 Economic characteristics

One of the purposes of the CertiQ scheme is to identify renewable electricity production and let the renewable producers receive the premium customers are willing to pay for 'green'. Therefore, economic characteristics are relevant, such as how the price of those certificates is developed and what contribution this has on the business case for renewable electricity generation capacity.

2.3.1 Price effects of electricity GOs

Three characteristics of the GO pricing will be discussed: the level, volatility and transparency. Both three aspects are considered to be relevant factors for business cases and market penetration of renewable capacities.

With regard to the price levels of electricity GOs, large differences are seen between the geographical origin and production pathways used to produce the electricity, as presented by Figure 3. On average, the lowest price is paid for imported GOs. It seems that for Europe as a whole, there is way less scarcity of certificates compared to the Netherlands. The Dutch prices have risen since 2012, when a lot of attention came for 'cheating power' retrieved by purchasing certificates from other countries [8] [9] [10]. It could be that the increased attention on the origin of consumed electricity would have led to a large scarcity in the Dutch certificate market, resulting in higher price levels especially for solar and wind generated electricity.

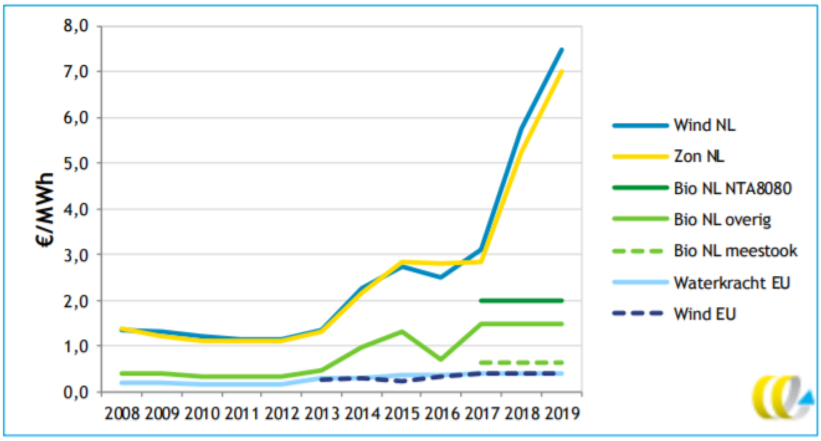


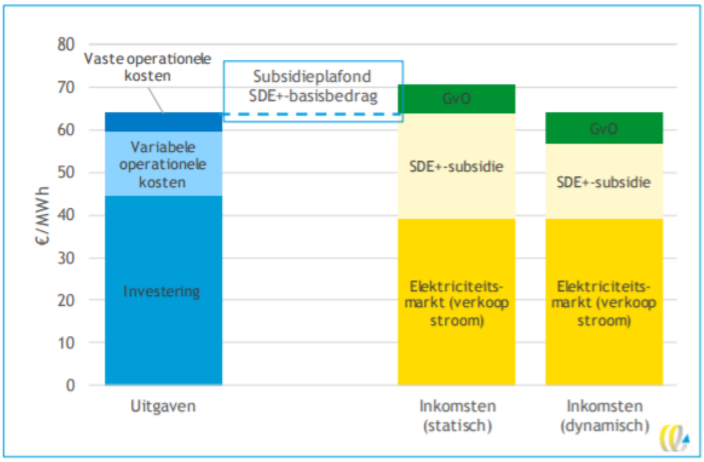
Figure 3: Average price levels of renewable electricity certificates divided in different categories [6]

Hulshof, Mulder & Jepma [12] stated that transparency of trade and prices is limited in European GO markets. The CertiQ electricity GOs seem to be no exemption in this, as no data on fluctuations in price of these certificates could be found. Hulshof, Mulder & Jepma [12] appoint that the volatility in electricity certificate prices is relatively high, although for Dutch wind (3.4%) and biomass (30.9%) this was relatively low in 2017, compared to other certificates such as Belgium wind for example (105.6%). They found that lack of transparency in pricing in the markets of electricity certificates is an important reason that results in the concerns of liquidity and volatility in those markets.

2.3.2 Schemes contribution to deployment

Effect of SDE and GO on the business case

Wielders et al. [6] investigated what impact Dutch electricity GOs have on the business case of renewable electricity generation technologies. As is represented in Figure 4, the major part of the gap between production costs and electricity revenues is closed by the SDE+ subsidy. The revenues of GOs can be received as additional value, but as the SDE+ subsidy has a competitive bidding element, it is assumable that the (expected) GO revenues should be used in order to obtain the subsidy. In this second case, the relative significant Dutch GO prices help to reduce the subsidy costs. However, the major part of the business case is closed by the SDE+ subsidy, which is mentioned to be similar for biomass and solar business cases [6].



Bron: Berekeningen CE Delft op basis van PBL (2019b).

Figure 4: Impact GO and SDE+ on business case of an onshore wind park (avg. wind speed 7.0-7.5 m/s) [6]

As the revenues of GOs could be taken into account to close the business cases, the way the GOs and physical electricity are purchased is important. Since this is mostly done by bilateral agreements that determine how the price of GOs and electricity is set and to what degree demand and investor security is guaranteed [6]. There are roughly three ways to purchase renewable electricity [6]:

1. Purchase of the physical electricity and GOs in the same contract at the electricity supplier, so there is no direct relation between the purchaser and the producers of the electricity and GOs.
2. Purchase of physical electricity at one party (e.g. electricity supplier) and the GOs at another party, without direct contact between purchaser and producers.
3. Purchase of physical electricity and GOs via a Power Purchase Agreement (PPA). This is a long term (mostly 10-15 years) contract between producer and consumer with all conditions pre-determined.

In practice, a trend is seen that financers require that renewable electricity investments have agreed the GO price and security of demand for a longer period, which is possible for all three ways to purchase renewable electricity.

PPA's have the advantage that the conditions can be customized towards the specific situations of the producer and consumer. Each PPA differs in agreements made on how the volumes and prices are set and the risks are divided. Some types of PPA's can be distinguished, this depends on if the purchaser is the end-consumer (Corporate PPA's) or a supplier (Merchant PPA's), a direct (On-site PPA) or grid connection (Off-site PPA) and if additional service providers are used to take some of the risks, such as balancing (e.g. Synthetic or Sleeved PPA's) [13].

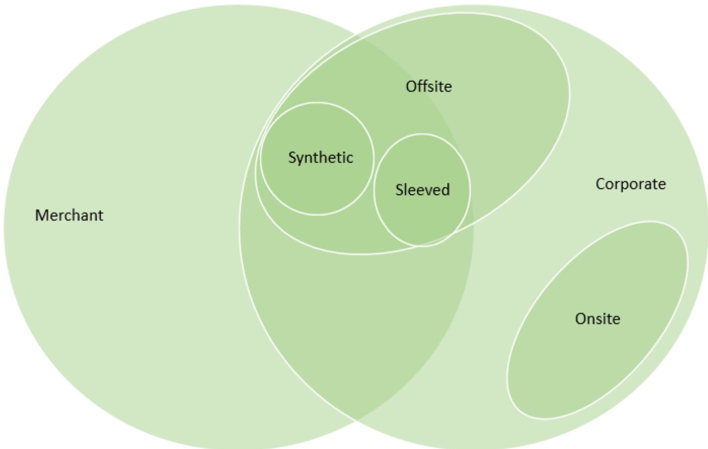


Figure 5: Overview different types of Power Purchase Agreements [13]

Especially large corporates are using PPA's more and more to purchase their electricity, as PPA's have a marketing value since consumers are ensured that they can show the location of their (domestic) produced renewable energy for the coming years. Besides, PPA's are used by producers and consumers of renewable electricity to reduce the uncertainty of the level and fluctuations in electricity prices as result of the increased penetration of variable renewable energy (VRE) sources, in order to secure the business case.

Actual deployment

In 2003, when the CertiQ GOs were introduced, around 1.5% of the total electricity production was produced by renewable sources. Until 2012, mainly renewable electricity produced with biomass was deployed in the Netherlands. At that time, around 10% of all electricity produced in the Netherlands was renewable. Thereafter, the renewable electricity capacities made a strong jump, mainly caused by a massive increase of solar PV and wind generation capacity [14]. The reason for this is suggested to be a combination of increased demand for Dutch renewable electricity, decreased costs of wind and solar PV technologies and the increase in revenues gained from Dutch electricity GOs for solar PV and wind. The developments of the share of produced renewable electricity in the total electricity use over time is shown in Figure 6.

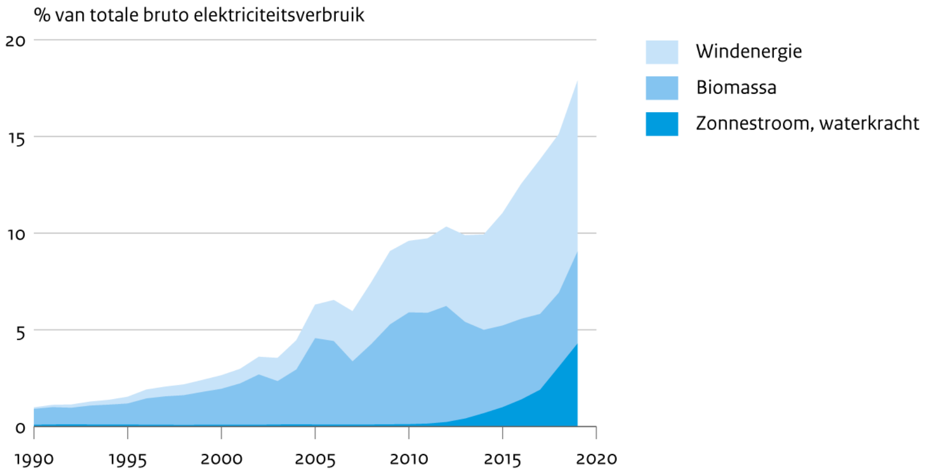


Figure 6: Share of renewable electricity in the Dutch electricity mix [15]

2.3.3 Finance of the scheme

The electricity GO scheme by CeriQ itself is financed by a membership contribution and fees for every certificate that is exchanged. The membership fee is 500 euro per year for traders and free for producers. The fees for issuing and trading certificates depend per type of certificate and are mostly allocated to the purchaser of the certificate [16].

The Dutch SDE+ subsidies are financed by additional taxes paid by electricity consumers, which were implemented in 1996. Since 2013, additional taxes called ‘Opslag Duurzame Energie en Klimaattransitie’ were implemented. Both taxes are paid per kWh of electricity used and the tariff differs by the amount of electricity that users consume yearly. Both tax levels of 2021 are represented in Table 3.

Table 3: Overview electricity taxes paid by Dutch consumers in 2021 [17]

Electricity taxes 2021	0-10,000 kWh	10,001-50,000 kWh	50,001-10 million kWh	more than 10 million kWh (private)	more than 10 million kWh (commercial)
General tax	€0.09428	€0.05164	€0.01375	€0.00113	€0.00056
ODE tax	€0.0300	€0.0411	€0.0225	€0.0004	€0.0004

2.4 Environmental characteristics

2.4.1 Emission mitigation impact of electricity GOs

GOs are originally intended to track and claim the way the consumed electricity is produced. However, the question if you can also claim CO_2 reduction as consumer or nation when you cancel electricity GOs is rather complex. First, some CO_2 allocation methodologies for electricity GOs are discussed and thereafter what questions arise if those ‘claimed’ effects can be seen as ‘real effects’.

Allocation of emissions for consumers who use electricity GOs

Wielders et al. [6] evaluates three allocation criteria for consumers, namely the Greenhouse Gas-protocol, the ‘CO_2-prestatieladder’ (‘CO_2 performance ladder’) and the PIANOo criterium. Those three criteria state that consumers that buy and cancel the GO can claim the full CO_2 reduction. However, the Greenhouse Gas-protocol describes that also the CO_2 emissions of the national grid mix should be reported and the CO_2-prestatieladder makes an exemption that power generated by biomass should not count for 0 g/kWh of CO_2 emissions. Wielders et al. [6] puts questions to these allocation criteria and propose an new allocation criteria based on the economic allocation, implying that only the allocation of greenhouse gas reductions should be based on the share that the GO contributed to the economic deployment of the renewable electricity generation capacity.

Allocation of emissions for national targets and impact of GOs

For national emission targets as stated in the Dutch Climate Agreement and Climate laws, the IPCC criteria are used for emission allocation. Those criteria allocate the emissions at the location and party 'at the fireplace' [18]. Therefore, in the Dutch National Energy Exploration emissions related to electricity are located at the electricity producers and not at the end-consumers. In other words, (international) exchange of physical electricity or electricity certificates has no impact on these targets at all.

Concluding, it is hard to relate carbon emission reductions to the use of electricity certificates, as these certificates are not purposed to prove carbon emission reductions, but only that a certain share fed into the electricity grid is renewable. Furthermore, GOs are effective in proving that the carbon emission impact of purchased electricity is limited or zero. However, it should be considered that according to the perspectives created by Wielders et al. [6], in the current Dutch system the low carbon emissions can be claimed by limited amount of GO purchasers, while actually the largest share of costs are paid by all consumers due to taxes.

2.4.2 Environmental impact of renewable electricity not covered by GOs

As GOs focus only on renewable energy in terms of climate impact, these certificates are not intended to provide information about other environmental characteristics, such as the effect of the electricity generation on biodiversity, use of finite minerals for the installations, land use or other environmental impacts. It therefore should be considered that a small part of sustainability is made traceable by the GOs and the environmental impact of other aspects should be taken into account as well.

3 Dutch green gas admixing

3.1 General and design characteristics

3.1.1 Establishment and purposes

Green gas (i.e. biomethane) is biogas that is upgraded to the conditions of natural gas. Biogas is produced from sludge and waste products and therefore considered as renewable. From 2003 until 2006, the production of biogas was stimulated via the MEP-regulation in the Netherlands. In 2008 a vision for green gas described that a green gas injection of 8-12% in the natural gas grid should be possible in 2020 [19], however in fact less than 1% of the Dutch gas consumption was 'green' in 2020. The MEP-regulations were followed up in 2008 by the SDE for biogas and in 2011 also green gas was included in the SDE+ subsidy. In 2009, Gasunie (Dutch and German gas TSO) established Vertogas to issue Guarantees of Origin for green gas. The main aim of the Vertogas certificates are to prove and guarantee that the gas is produced according to the green criteria, in order to facilitate and stimulate trade in green gas and development of a green gas market [20].

3.1.2 Design of the scheme

Potential green gas producers can be approved by the grid operator and registered in the Vertogas register. Then, for every MWh of green injected in the gas grid, and measured by a measurement party, a certificate (GO) is earned. Traders and consumers can buy certificates additionally to the physical gas that they bought, to prove the greenness of the gas. So, the physical green gas is injected to the natural gas grid and traded on the physical gas market, and certificates are traded in a virtual certificate market. The tradable Vertogas certificates require mass balancing, meaning that the gas should be injected to the public gas grid in order to obtain the certificates.

For biogas or green gas that is locally used and not injected into the gas grid, special GOs 'without grid' can be obtained, which are not freely tradeable. Still, those certificates can be used by the local consumer itself to prove its greenness.

Since 2015, traders can book the green gas certificates to the NEa, in order to obtain HBEs. In 2019 this was done for 18% of the green gas [14].

Since 2018, European biomethane certificates can be exchanged internationally due to the establishment of the European Renewable Gas Registry (ERGaR)[4] and revision of the REDII [21]. Nevertheless, the market is less mature and volumes (in terms of TWh) are significantly lower than those of the electricity GOs.

3.1.3 Introduction of the scheme

Gasunie established Vertogas on 2 July 2009 for the purpose of issuing certificates which guarantee the origin and volume produced of green gas. Gasunie set up its subsidiary Vertogas at the request of the Ministry of Economic Affairs and in collaboration with market parties. Since then, Vertogas has been responsible for green gas certification in the Netherlands. The certificates show that the gas is generated from biomass or renewable sources.

[4] The ERGaR in an organisation including members organisations related to biomethane GOs throughout Europe

Legal status

On 6 September 2011, during the launch of Groen Gas Nederland, the Dutch Minister of Economic Affairs, Agriculture and Innovation (EL&I)[5] announced that Vertogas should hold a legal status as a certifier of green gas [22].

Since 1 January 2015, the role of Vertogas as a certifier of renewable gas (green gas) has changed. Vertogas acts on behalf of the Minister of Economic Affairs from 1 January 2015 and carrying out its duties on the basis of the new energy legislation, which also includes the certification of renewable energy. A recognized green gas certificate system is one of the preconditions for the further development of a properly functioning and transparent market for the trade of green gas. Vertogas now acts on behalf of the minister, who bears ultimate responsibility for the certification process [23].

Vertogas is a 100% subsidiary of Gasunie and a certification institute. The institute only has a facilitating role and has no influence on the market. The certificates guarantee the origin and production method of the renewable gas and give it a certain value. For example, a certificate cannot relate to gas that has been CO_2 compensated (e.g. by planting trees elsewhere). This provides market parties with certainty that it is actually green gas [24].

Vertogas is a so-called 'upstream' certifier. This means that the certificate only gives a guarantee of origin and says nothing about the end user. Vertogas therefore does not maintain a mass balance system. The certification data can serve as input for such a system. A producer can also ask Vertogas to supply data to the NL Agency (SenterNovem[6]) in order to obtain a subsidy under the Sustainable Energy Incentive Scheme [24].

Vertogas operates within the frameworks established by national and international regulators. Vertogas wants to set an example at European level in order to support the international trade in green gas [24].

Participants' council

Vertogas has been working with a participants' council ever since its creation. A participants' council is composed of delegations of both traders and producers.

Formal consultations are carried out between Vertogas and the participants' council three times a year. During these, the council discusses policy issues, future scenarios, trends in the market and in Europe and proposed changes to the platform [25].

The current members of the council are:

- ACT Commodities
- Attero
- Essent
- Greenchoice
- HoSt
- Nederlandse Emissie Autoriteit
- Omrin B.R.F.
- Pitpoint

[5] This was the name of the Ministry of Economic Affairs in the period 2010-2012. When the Rutte I cabinet was formed, the Ministry of Agriculture, Nature and Food Safety was abolished. Food safety was transferred to the Ministry of Health, Welfare and Sport. In 2012, the name of the ministry was again changed to Economic Affairs.

[6] In 2010, SenterNovem became part of Agency NL. Since 2014, Agency NL was merged into RVO.

- SuikerUnie

Cross border cooperation

At the end of 2010, the Dutch green gas certification body Vertogas and the German Biogas Register[7] enabled cross-border trade in certified biogas, by means of a letter of intent for cooperation. The intention behind it, was to have mutual recognition of certificates, thus creating an international green gas market [26].

The collaboration makes it possible for a Dutch customer to buy green gas that already meets European standards (set in the European Renewable Energy Directive, 2009/28/EC) since the German certificates comply with them [26].

3.2 Legislative characteristics

3.2.1 Combination with other regulations and support schemes

SDE+

Similar to the electricity GOs, GOs for green gas are not the primary tool to support investments in green gas production installations. Since 2011, the SDE+ provides subsidies for green gas production. Green gas producers have to apply at Vertogas in order to obtain the subsidy. Hereby, the data that is required for the RVO to provide the subsidies, can be obtained from Vertogas [27]. Hence, the definitions used and information provided by the Vertogas certification system are aligned with the criteria to obtain the SDE+ subsidy.

Fuel blending obligation

As stated in the previous section, Vertogas certificates can be interchanged with HBE's, which can be used to comply to the Dutch fuel blending obligation. The type of HBE (advanced, conventional or other) that is received depends on the resource that is used to produce the green gas, as stated on the Vertogas certificate according to the NTA8003 codes [28]. This means that the Vertogas certificates are compliant with the RED-II art. 19 specifications for Guarantees of Origin and RED-II art. 25-31 specifications for targets in the transportation sector.

On the certificates itself, it is stated if the produced biomethane received SDE subsidy or not. Only unsubsidized biomethane certificates can be used to obtain HBEs to meet the fuel quota, in order to overcome double support of the same produced volumes of biomethane. Therefore, investors of new production capacities should make a choice between the revenues of the SDE subsidy or the revenues of the HBEs that can be sold.

3.2.2 International interactions

The previous section already described that the international exchange of biomethane certificates was realised in 2018, by the establishment of the ERGaR. Also, European standards created by the CEN in 2016 for injecting biomethane into the natural gas network and some bilateral and multilateral agreements between national registries increased the international trade of biomethane [29]. Before that time, import of certificates was not possible since other certificates than the Vertogas certificates were not recognized by the Dutch law and therefore had no value. Contrary to import, export of Vertogas certificates was possible already earlier as some other countries accepted the Vertogas certificates [30]. Although international trade is increasing, less than 10% of the total produced biomethane is traded internationally. The international trade is still limited by the fact that most

[7] The Deutsche Energie-Agentur GmbH, DENA, operates the 'Biogasregister Deutschland', an electronic, account-based documentation system for the management of quality certificates for biogas. The system offers users the possibility to manage biogas quantities regarding size, quality and origin within a uniform documentation system and to make this information available to other users.

countries apply national mass balancing requirements [29]. The major trends in importing and exporting countries are determined by national support schemes and targets that could be based on production (e.g. Germany and Denmark) or end-use (e.g. Sweden) [29]. The Netherlands has a relative small share of internationally exchanged certificates in Europe (see Figure 7).

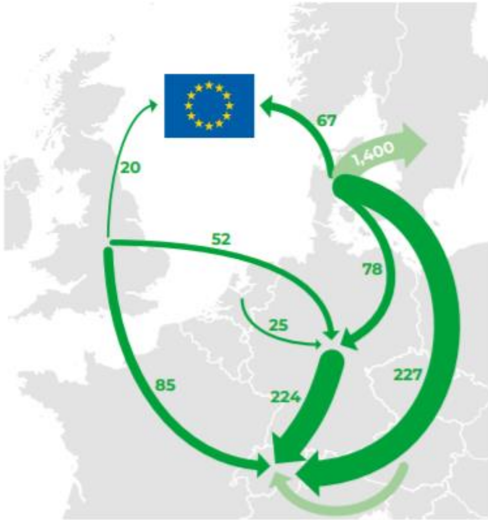


Figure 7: European trade volumes of biomethane certificates in 2019 [29] [31]

3.2.3 Reliability of the scheme

In the past, there have been issues with regards to the reliability of the Vertogas scheme. It was found that some of the green gas producers blended invalid sources in their biomass streams in order to obtain more certificates. At two points in time, the criteria for the biomass used were sharpened. In 2011, the NTA 8080:2007[8] criteria were set on the biomass in order to improve the quality standards and transparency of the resources used. In 2019, these standards were updated towards the NTA 8080:2017 criteria, involving extra assurance reports for (co-)manure digesters. It is always difficult to guarantee that producers cannot cheat on the certification protocols, as some might have discovered previously unknown methods of cheating the system.

3.3 Economic characteristics

3.3.1 Price effects of green gas certificates

Similar to the prices of renewable electricity GOs, also prices of green gas GOs lack transparency and large differences in prices paid for these certificates are experienced. The prices of green gas GOs are agreed in bilateral contracts as well and according to the Green Gas Panorama this price depends on the duration of the contract, the volumes traded, the type of biomass used and the end-user market that the certificate is sold to [32]. There is very few information available about the development of these prices, although it is stated that there was a relative large price range between 5 and 15 euro/MWh in the last years [32]. The price level of the Vertogas green gas GOs (5-15 euro/MWh) is relatively high compared to the price paid for natural gas in the Netherlands (approximately 13 euro/MWh in 2021). Hellemans Energy Consultancy stated that in 2018 around 60% more was paid for green gas compared to natural gas excluding taxes, and 10-20% more including taxes [33]. It seems that buying the scarce green gas certificates is one of the only ways to ‘green’ gas production. Another methodology that is used, is to buy carbon reduction certificates from carbon reduction initiatives all over the world equal to all CO_2 that is emitted during the production and use of natural gas. This

[8] The NTA 8080 is a standard that aims to define sustainability for all kinds of (international) biomass, also known as the ‘Better Biomass Certificate’.

method includes lower costs but seems to have less marketing value than using the green gas certificates [33].

3.3.2 Schemes contribution to deployment

Effect of SDE and GO on the business case

Although the price paid for the green gas certificates is relatively high compared to the price paid for gas from the grid, the certificate scheme is not the major factor in closing the unprofitable gap between the natural gas and biomethane production costs (see Figure 8). The biomethane production costs are significantly larger than the natural gas production costs. In Figure 8 is seen that in a large scale digester business case based on the assumptions proposed by the SDE scheme, only 22% of the business case costs are covered by the sold gas physically [32]. 13% is covered by the GO price and 65% is covered by the SDE++ subsidy, which shows that the price paid for the GOs is relatively small compared to the production costs and the major share of the business case are currently covered by the SDE++ subsidy. The left side of Figure 8 shows that the SDE++ subsidy does not guarantee that the unprofitable gap is closed. The 'Basisbedrag' (base amount) corresponds with the production cost price of biomethane and the 'compensatiebedrag' (compensation amount) with the gas market price. The maximum subsidized amount is the difference between the 'basisbedrag' and 'basisenergieprijs' (base energy price). If the actual gas price drops below the assumed base energy price, a gap between the costs and revenues appears. Currently, the natural gas price is around 13 euro/MWh and there are some biomethane producers that accepted a base energy price of 20 euro/MWh, resulting in a gap of 7 euro/MWh if the gas prices remain at this low level [32].

The price of the renewable premium for green gas is not taken into account by the gas market price assumed by the SDE (i.e. only the price of the physical gas is taken into account and not the price of the GO). This means that in theory the unprofitable gap can be filled by the SDE subsidy and revenues of the GOs could be used as additional profits, which could be perceived as windfall profits. In practice, investors in biomethane production capacities may be required to use the income of the GOs, in order to compete with other projects in the application process for the SDE budget.

Additionally, it should be mentioned that since the certificates for biomethane without grid connection cannot be traded, no additional GO revenues can be obtained for these GOs.

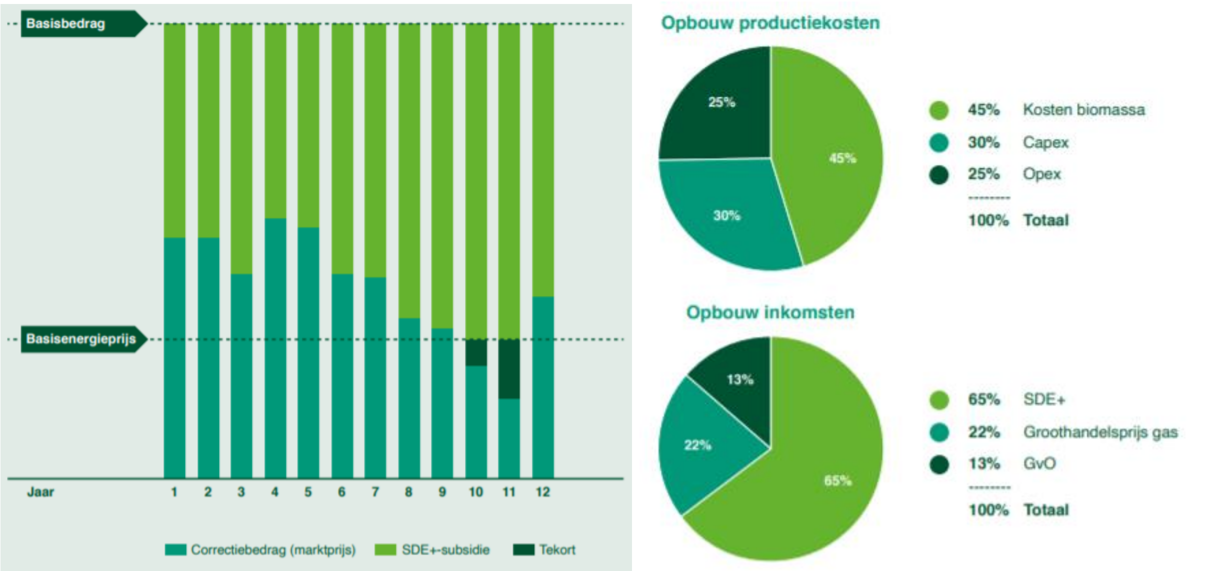


Figure 8: The SDE subsidy level (left) and production costs and revenues (right) of biomethane production [32]

Actual deployment

In contrast to predictions in 2008 that 8-12% of the natural gas being replaced by biomethane in 2020, less than 1% of the Dutch gas consumption was biomethane in 2020. Until 2010, all the green gas was produced by gas from waste processors, but this share decreased due to less availability of this type of waste [14]. The effects of the implementation of the SDE+ (2012) and SDE++ (2018) are visible in the production levels of biomethane from biogas and manure fermentation. Also the effects of the connection created in 2018 between the biomethane GOs and HBEs is visible, since then the use of biomethane in the transport sector rapidly increased to 790 TJ in 2019, representing 18% of all green gas consumption in the Netherlands [14].

	Productie						Aandeel
	uit stortgas	uit RWZI-gas	uit mestvergisting	uit overig biogas	totaal	totaal	in totaal aardgas-verbruik
	mln m^3					TJ[1)]	%
2000	17				17	549	0,04
2005	14				14	446	0,03
2010	11				11	345	0,02
2015	6	.	.	74	80	2 523	0,21
2016	5	.	.	78	83	2 620	0,21
2017	5	.	.	93	98	3 100	0,24
2018	4	2	20	80	107	3 375	0,27
2019**	4	4	51	84	142	4 497	0,34

Bron: CBS
1) Onderwaarde.

Figure 9: Biomethane volumes that were injected into the natural gas grid over the years [14]

Some reasons are given for the relatively small deployment of biomethane in the literature:

- Most biomass comes from several small sources and biogas production is located at farms on small scale, while volumes should be larger to make the business case of upgrading biogas to biomethane by methanation more profitable [34].
- Injecting green gas into the local gas grids might not always be possible due to capacity limitations. Therefore grid operators should adjust specific elements of the grid and barriers in legislations should be overcome [35].
- The regulatory support for biogas is mainly based on stimulating direct electricity and heat production instead of upgrading to biomethane [36]. For example in the SDE+ and SDE++, the subsidy budget is used for the most cost effective green energy production technologies, in which other technologies (e.g. biomass use in CHP plants), mainly to produce electricity, were more cost effective than biomethane production [37]. In 2020 the criteria changed to the most cost effective technologies in terms of CO_2 reduction, which improved the position of biomethane business cases but still the SDE budget seems to be utilized to stimulate other technologies [32]. In 2019 32% of the biogas was upgraded to green gas and according to the National Energy Exploration this should rise to 75% in 2030, in order to meet climate targets [38].

3.3.3 Finance of the scheme

The green gas GO scheme by Vertogas itself is financed by a membership contribution and fees for every certificate that is exchanged. The membership fee is 4060 euro per year for traders, 914 euro per year for producers and for end-users participation is free. The fees for issuing and trading certificates depend per type of certificate and are accounted to the purchaser of the certificate [39].

The Dutch SDE+(+) subsidies are financed by additional taxes paid by gas consumers and revenues that the Dutch state made by the deployment of the Groningen gas field. Since 2013, taxes called 'Opslag Duurzame Energie' were implemented next to the usual taxes users had to pay. The taxes are paid per m^3 of natural gas used and the tariff differs by the amount of gas that users consume yearly. Both tax levels of 2021 are represented in Table 4: Overview (natural) gas taxes paid by Dutch consumers in 2021 Table 4 [17]. For CNG used in vehicles and gas used in the horticultural sector, other tariffs are used.

Table 4: Overview (natural) gas taxes paid by Dutch consumers in 2021 [17]

Natural gas taxes 2021	0-170,000 m^3	171,001-1 million m^3	1 million - 10 million m^3	more than 10 million m^3
General tax	€0.34856	€0.06547	€0.02386	€0.01281
ODE tax	€0.0851	€0.0235	€0.0232	€0.0232

3.4 Environmental characteristics

3.4.1 Emission mitigation impact of green gas GOs

As long as there is relatively less international trade of biomethane GOs, the chance is big that buying biomethane GOs helps to encourage more biomethane production in the Netherlands. Because biomethane has similar molecular structure as natural gas (CH_4), carbon emissions are still emitted when this type of gas is burned. However, the difference between the relatively short CO_2 cycle (mostly <5 years, except from wood) of biomass compared to the long CO_2 cycles (>100 millions of years) of fossil sources makes biomethane to be perceived as no major contributor on the CO_2 level in the atmosphere. Nevertheless, more downstream in the chain emissions occur for harvesting, transport, storage and processing the biomass. The Renewable Energy Directive (Directive 2009/28/EC) mandates to make the greenhouse gas impact of biofuels traceable though the value chain. Therefore, the CO_2 reductions compared to a fossil reference are shown on the Vertogas certificate, based on European calculation standards taking into account standard values for certain types of biomass and application of allocation methods for emissions to waste, co-products, cogeneration and carbon capture and storage [40] [41].

3.4.2 Limited availability of biomass

When biomass is used, it should be taken into account that all types of biomass have their own characteristics, their (sustainable) availability is limited and they can mostly be used for only one purpose. In other words, when biomass is used to produce electricity, it cannot be used to produce biomethane anymore, and the same counts for other sectors where some types of biomass can be utilized for 'high value purposes'. Using biomass for energy purposes has built a bad reputation due to forests that were felled for biomass used in former coal fired plants or tropical forests that were felled to use the palm oil for biofuel production.

The Social Economic Council (SER)[9] provided recommendations on the biomass use in the Netherlands and in 2020 also a 'Roadmap for National Bioresources' was created. From that, it can be concluded that there are opportunities for biomass sources that can be used to create sustainable biomethane and biogas chains. First, small and medium scale digestion of manure has potential to produce 0.9 billion Nm^3 of biomethane per year in the Netherlands, aligning the food chains and limits of the earth [42]. Second, large scale gasification seems more efficient than digestion but less adaptable in the

[9] This is the most important advising council of the Dutch Government about social-economic issues, the council includes members that are employees, entrepreneurs and independent experts

natural cycles. Nonetheless, some wet types of biomass, such as sewage sludge, seem applicable for this, as they do not have any other valuable purposes [42]. After the production of biomethane, there should be ensured that it will be used in applications where the least attractive alternatives are available. Furthermore, it should be considered what the biomethane is replacing, as for example replacing 1 MWh of natural gas by 1 MWh of biomethane leads to other amounts of emission reduction than replacing 1 MWh of diesel by 1 MWh of biomethane.

4 Dutch fuel mandatory blending quota

The Energy for Transport compliance system

4.1 General and design characteristics

Companies that supply fuel to the Dutch transportation sector are required to deliver an increasing share of renewable energy each year, rising to 16.4 % in 2020. This is the annual obligation for petrol and diesel delivered to transport applications in the Netherlands.

As stated by the Dutch Emissions Authority[10], companies in the Netherlands that deliver more than 500,000 litres, kilograms and/or normal cubic metres (Nm^3) fuel to the transportation sector are subject to obligations based on the Energy for Transport legislation.

The system makes it mandatory for these companies to submit their duty-paid fuel deliveries annually, which in turn is used to determine their annual obligation and their obligation to reduce greenhouse gas emissions. The total amount of fuels delivered by a company to transport destinations subject to an obligation in the Netherlands is referred to as 'taxed delivery of transport use' ('*Uitslag tot vervoersgebruik*' (UtV)) [43].

It is mandatory to register the delivery of the following fuels [43]:

- Petrol (unleaded light oil or mineral oil that is taxed at the unleaded light oil rate),
- Diesel (gas oil or mineral oil that is taxed at the gas oil rate),
- Liquefied petroleum gas (LPG, or mineral oil that is taxed at the LPG rate, such as liquefied natural gas (LNG)),
- Compressed natural gas (CNG),
- Other liquid and gaseous biofuels.

To the following modes of transport [43]:

- Road vehicles,
- Rail vehicles,
- Non-road mobile machinery,
- Agricultural and forestry tractors,
- Recreational craft when not at sea.

The annual obligation only applies to the following fuels:

- Petrol (unleaded light oil or mineral oil that is taxed at the unleaded light oil rate),
- Diesel (gas oil or mineral oil that is taxed at the gas oil rate).

Companies are obliged to register their total amounts of petrol and diesel (including its bio-components) that has been delivered to transport destinations. This amount is known as the 'taxed delivery for final consumption' (Lte: *levering tot eindverbruik*), and they comply with their registry obligation using the Energy for Transport Registry (REV: *Register Energie voor Vervoer*).

The Energy for Transport legislation gives for granted that the quantities of LNG, LPG and CNG have not been delivered to a transport customer subject to an obligation. Nevertheless, if the company states that the delivery (or part of it) was indeed to this type of transport destination, the amounts can be included by presenting proof of payment and an invoice.

[10] Dutch Emissions Authority (Nederlandse Emissieautoriteit, NEa) https://www.emissionsauthority.nl/

4.1.1 Renewable fuel units (HBEs: hernieuwbare brandstofeenheden)

The use of renewable fuel units is used to meet these obligations (HBEs). When a delivery of renewable fuel is claimed by a party, an HBE is created by the Dutch Emissions Authority within the Energy for Transport Registry (REV) and is equal to one gigajoule (1GJ) of renewable fuel. HBEs are traded, so obligated parties can either produce them themselves or purchase them from those who produce renewable fuels [44].

There are three types of HBE: HBE Advanced, HBE Conventional and HBE Other.

Companies subject to an annual obligation require a minimum share of HBE Advanced (HBE-A) and may use a maximum share of HBE Conventional (HBE-C). HBE Other (HBE-O) is used for the remaining share of the annual obligation.

The feedstock in the claim for delivery of renewable energy determines the type of HBE that is created. The Figure 10 below shows the origin of various types of HBEs.

Type of HBE	Created by claiming delivery of	Further description
HBE Advanced	Liquid or gaseous advanced biofuel	Biofuel produced from feedstocks mentioned in Annex IX, Part A of the Renewable Energy Directive
	Liquid or gaseous renewable fuel	Fuel where the energy-content comes from renewable energy sources other than biomass
HBE Conventional	Liquid or gaseous conventional biofuel	Biofuel produced from agricultural and energy crops
HBE Other	Other liquid or gaseous biofuel	Biofuel produced from feedstocks mentioned in Annex IX, part B of the Renewable Energy Directive
		Biofuel produced from feedstocks NOT mentioned in Annex IX of the Renewable Energy Directive and which do NOT come from agricultural and energy crops
	Electricity	The renewable part, based on the European determined forfait

Figure 10: Origin of various types of HBEs (Source: Dutch Emissions Authority [44])

4.1.2 Procedure

Companies comply with their annual obligation by surrendering sufficient HBEs of the correct type in the Energy for Transport Registry (REV) on 1st April of the subsequent year. In addition, they must have sufficient HBEs of the correct type in their account to comply with their annual obligation no later than 31st March.

On 1st April the REV debits the number of HBEs per type that equates to the annual obligation. Then, the REV debits the remaining HBEs, with the exception of the amount that the operator is allowed to carry over to the next year.

The REV debits the HBEs in a fixed order until the total annual obligation is complied with:

1. the number of HBE-A required for the sub-target,
2. the number of HBE-C available up to the limit,
3. the number of HBE-O available,
4. the number of HBE-A available,

5. if necessary, an additional number of HBE-C, insofar as the limit has not yet been exceeded,
6. if necessary, an additional number of HBE-O.

The banking limit is filled in a fixed order: first using the HBE-A available, then using the HBE-O available and finally using the HBE-C.

4.1.3 Banking limit

If companies have a surplus of HBEs on their account after debiting renewable energy units (HBEs) to comply with their own obligations, they can carry over several HBEs to the next year on 1 April. This is the balance banked.

The banking limit depends on the capacity of the account holder. The general principle is that a balance of 2000 HBEs or less can always be banked (see Figure 11 for the specifications).

The banking limit is filled automatically based on the available HBEs, where any remaining HBE-As on the account are first banked, followed by HBE-Os and lastly by HBE-Cs.

The amount of HBEs on the account exceeding the banking limit will expire on 1 April.

This is also the case when a negative balance occurs for one or more of the HBE-types after the REV debits HBE's for the annual obligation. The amount of HBE's above the banking limit cannot be compensated with a negative balance for any HBE-type. This means that the amount of HBE's above the banking limit will always expire, regardless of a possible negative balance for a specific HBE-type.

The REV automatically performs the banking transactions during year-end closing, where the highest number applies.

Banking limit for:	# HBEs		
Company subject to obligations	2,000	or	25% of annual obligation or obligation to reduce emissions
Claiming company subject to obligations	2,000	or	10% or 25%
Claiming company	2,000	or	10% of the total claims
Transferer	2,000		

Figure 11: Level of banking limit (Source: Dutch Emissions Authority [44])

4.1.4 CO_2 reductions

The NEa assigns a reduction contribution to each HBE in kilograms of $CO_{2\text{-eq}}$: the "HBE reduction contribution”. Thus, a company reduces CO_2 emissions by deploying the HBEs required for their annual obligation. The RED was implemented via amendments to the Environmental Management Act (*Wet Milieubeheer*), alongside a Decree on the Renewable Energy for Transport (*Besluit hernieuwbare energie vervoer*) and the Regulation on Renewable Energy for Transport (*Regeling hernieuwbare energie vervoer*). These resulted in the Renewable Fuel Obligation (HEV) and obligate registered parties to deliver the renewable fuel target [45]. These obligations are managed by the use of renewable fuel units (HBEs).

4.1.5 Introduction of the scheme

The Act implementing the biofuels provisions of the Renewable Energy Directive (2009/28/EC) ("RED") in the Netherlands (the "Act") was published in March 2011 and entered into force with retroactive effect as of 1 January 2011 [46]. In this way, the EU RED was transposed into Dutch national legislation, requiring fuel suppliers to meet 10.4% renewable fuel targets in transportation in 2018, 13.2% in 2019, and 16.4% in 2020. This figure is higher than the RED's prediction of 10% by 2020.

Below follows a summary of the key elements of the scheme implementation as explained by Ref. [46]:

In force as of 01 January 2011

The RED's implementation deadline was December 5, 2010. As a result, the majority of the Act's, Decree's, and Regulation's provisions took effect retroactively on January 1, 2011. As a result, the Biofuels Road Transport Decree of 2007 (*Besluit biobrandstoffen wegverkeer 2007*) has been repealed, and its accompanying regulations, such as the Biofuels Road Transport Administration Regulations (*Regeling administratie biobrandstoffen wegverkeer*) and the Regulation on Double Counting of Better Biofuels (*Regeling dubbeltelling betere brandstoffen*), have expired [46].

Obligated parties

The Netherlands encourages the use of biofuels by requiring licensees of excise warehouses (*accijnsgoederenplaats*) to release (*uitslaan*) a certain percentage of biofuels per year as part of their total fuel release. The annual target under the new Decree applies to so-called obligated registered parties (*registratieplichtigen*), which include all excise warehouse permit holders and registered consignees (*geregistreerde geadresseerden*) who store or release petrol, diesel, and biofuels for consumer use. In addition, producers of biogas and electricity for transportation may choose to participate in the bioticket (HBEs) trade on a voluntary basis [46].

Monitoring and administration of the scheme

The Decree establishes an automated central register managed by the Netherlands Emission Authority (NEa) to monitor the flow of biofuels and administer the share of energy from renewable sources in transportation. Each obligated registered party (as well as each voluntary registered party) must create an account in the register to manage their biofuels transactions, including the biofuels' characteristics. The register also oversees the resale of biofuels, the trade in bio-tickets, and other forms of renewable transportation energy such as electricity.

Compliance with sustainability criteria and required declarations

Renewable energy may only contribute to the achievement of the targets if the RED's sustainability criteria are met, according to the Decree.

Declaration of verification: An audit by an accredited auditor on the basis of a sustainability scheme can be used to demonstrate compliance with sustainability criteria (or certification scheme). Obligated registered parties must provide a verification declaration in accordance with the model provided in the Regulation to this effect. The European Commission or the relevant Dutch minister must approve the implemented sustainability scheme based on a Dutch verification protocol.

Only biofuels produced after July 1, 2011 or entries made after July 1, 2011 were subject to the requirement to provide a verification declaration to that effect. The lack of accepted certification systems at the start of 2011 was the reason for this. As a result, the Ministry of Infrastructure and Environment appears to have accepted that no proof of compliance with the sustainability criteria could be provided until July 1, 2011.

Sustainability declaration: Any transfer of biofuel consignments to another obligated registered party or to another country must be accompanied by a sustainability declaration. This document must accompany any physical transaction of biofuels after their first entry into the Netherlands and contains information about the sustainability criteria of biofuels.

Declaration of double counting: The targets are calculated based on the energy content (caloric value) of biofuels rather than the volume of biofuels brought to market. To meet the mandatory target, the energy content of biofuels made from wastes, residues, non-food cellulosic material, and lingo-cellulosic material, also known as second-generation biofuels, can be doubled. In addition to the biofuels balance, a double counting declaration in accordance with the model provided by the Regulation, as well as a declaration based on the Dutch Verification protocol on double counting of biofuels, must be submitted with the first entry of such biofuel (published on the website of the NEA). Double counting is nothing new in the Netherlands. Previously, the Regulations on Double Counting of Better Biofuels allowed for double counting.

Sanctioning

Non-compliance with the Act's, Decree's, and Regulation's obligations may be considered a criminal offense. Administrative penalties (*bestuurlijke boete*) or orders for periodic penalty payments (*dwangsom*) may also be imposed. In addition, compensation for target obligations must be paid the following year.

4.2 Legislative characteristics

The provisions of the EU Directive on Renewable Energy were incorporated into national legislation by the Dutch parliament in 2011. The EU Directive establishes aggressive targets for all Member States to increase the proportion of energy derived from renewable sources, including biofuels, to 20% by 2020, and 10% by the same year in the transportation sector [47].

National Targets

The Energy for Transport legislation stated that the overall mandatory share of renewable energy for 2018 to be set at 8.5% of the energy content in the transport sector. The mandatory share steadily increases in subsequent years, reaching 16.4% in 2020.

Furthermore, the annual requirement is subdivided beginning in 2018, with a (minimum) sub-target for the use of advanced biofuels (from waste and/or residues) and a cap on the use of conventional biofuels (from agricultural crops).

Year	2018	2019	2020
Total	8.5%	12.5%	16.4%
Minimum advanced	0.6%	0.8%	1.0%
Maximum conventional	3.0%	4.0%	5.0%

Figure 12: Share of renewable energy as percentage of energy content (source: 'NEa')

The annual obligation is expressed in three different types of renewable energy units (HBEs: *hernieuwbare brandstofeenheden*):

1. HBE Advanced (HBE-A) for the sub-target,
2. HBE Conventional (HBE-C) for the limit,
3. HBE Other (HBE-O) for the rest.

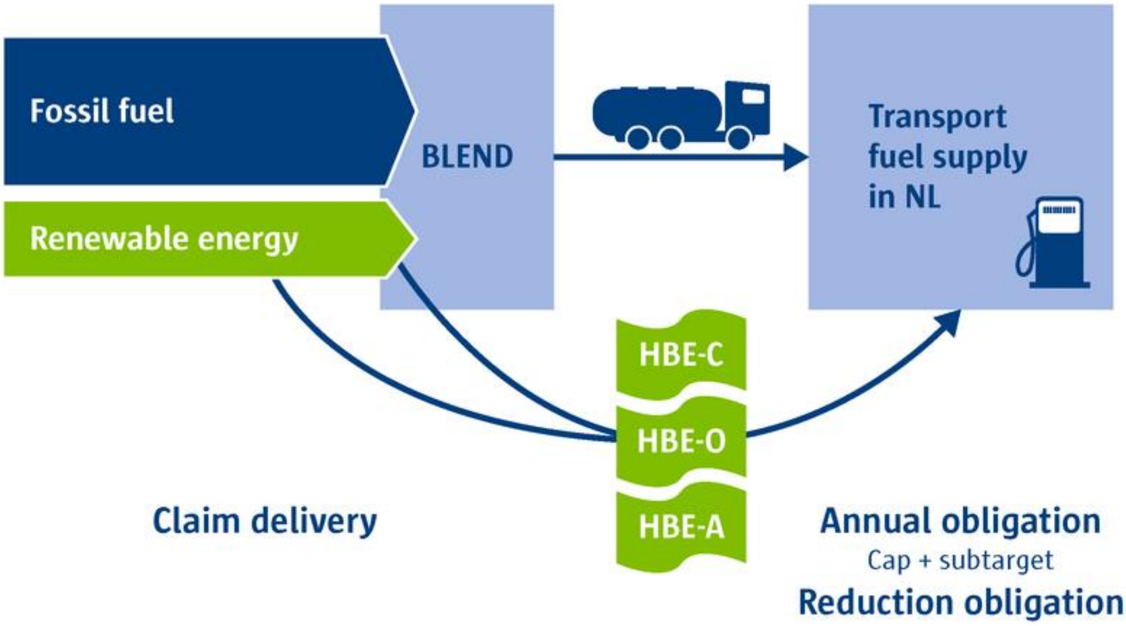


Figure 13: Renewable energy units (source: 'Dutch Emissions Authority')

4.2.1 Amount of the annual obligation 2020

According to NEa, all fuel suppliers in the Netherlands met their annual obligation in 2020 reaching a joint share of 16.5% renewable energy, a figure slightly higher than the mandatory share of 16.4%. The Netherlands Emissions Authority explains that it was possible to meet the quota given that the higher mandatory share – compared to 12.5% in 2019 – was offset by a pronounced decrease (13% lower than in 2019) in fuel demand due to the corona measures.

Regarding the types of renewable energy used in 2020, the NEa reports showed a very similar composition as in 2019, with Diesel replacement biofuels (e.g. FAME, HVO, FAEE) making up for the majority of renewable energy at 75%, followed by gasoline replacement biofuels (e.g. bio-ethanol, bio-naphtha, bio-ETBE, bio-methanol) at 19%. The remaining 6% renewable energy for transport mainly concerns electricity and biogas.

EUROPEAN TARGETS

10% RENEWABLE ENERGY IN TRANSPORT BY 2020

The Renewable Energy Directive (RED) required that 10% of the petrol and diesel supplied to the Dutch transport market in 2020 be replaced by renewable alternatives. According to the Fuel Quality Directive (FQD), there is also a 6% reduction in greenhouse gas emissions in the fuel chain for 2020.

The Netherlands appears to be well above the RED target, with 16.5 percent renewable energy. However, nearly 30% of biofuels were delivered to seagoing shipping by 2020. Deliveries of sustainable biofuels to shipping do contribute to the Dutch annual obligation, but not to the European target of 10%. When sea shipping supplies are excluded, the share of renewable energy in Dutch transportation falls to 11.7%.

6% CO_2 REDUCTION BY 2020

The Renewable Energy Directive (RED) required a 6% CO_2 reduction in the fuel chain by 2020. This involved the reduction of greenhouse gas emissions throughout the fuel chain, from extraction to production and combustion in engines, the so-called “well-to-wheel” chain emissions.

The NEa 2020 report states that the CO_2 reduction in the fuel chain as a whole was well above 6%. However, national reporting to Europe is based on 2020 deliveries, and the emission reduction achieved by deliveries to seagoing shipping may not be counted under EU calculation rules. Because approximately 30% of biofuel deliveries to shipping occurred in 2020, a large portion of the invoices were not included.

In 2010, the starting point was 94.1 grams of CO_2 per megajoule. To achieve a 6% reduction in 2020, the average emission factor had to fall to 88.5. In 2020, the average emission factor of the reported fuel mix for total transport in the Netherlands was 89.0 grams $CO_{2\text{-eq}}$ / MJ, representing a 5.4% reduction compared to the European baseline standard. The total CO_2 emission reduction achieved across the entire chain was 2.087 kton in 2020.

4.2.2 Beyond 2020

In the RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. The Commission’s original proposal did not include a transport sub-target, which has been introduced by co-legislators in the final agreement: Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy. The new RED II directive must be implemented into Dutch law by June 30, 2021.

In order to comply with the EU's revised Renewable Energy Directive (RED II), the Dutch government intends to make significant changes to the country's biofuels legislation. A draft law introduced in December 2020 would gradually increase the Dutch biofuel quota, which specifies the minimum energy share of renewables in transportation, from 16.4 % in 2022 to 27.1 % in 2030.

The draft law also requires suppliers of heavy fuel oil and diesel for inland shipping to participate in the renewable fuel unit (HBE) scheme on an annual basis. Only advanced biofuels used in maritime shipping will be eligible for HBE generation beginning in 2022.

4.3 Economic characteristics

Through the Stimulation of Sustainable Energy Production Scheme (SDE++) program, the Dutch government intends to invest €200 million in advanced biofuels and electro-fuels [48].

Consumers: The costs are borne by the consumers.

Distribution mechanism: Companies pass on the costs arising from the quota obligation to the consumers by adding a surcharge to their fuels.

As suppliers have the option of producing or purchasing the physical product or the certificate, the value of an HBE should be equal to the cost of a GJ of renewable fuel. This price has risen in recent years, owing to increasing blend mandates requiring the incorporation of the (expensive) renewable diesel as the biodiesel (FAME) blend wall has been reached. However, there are other factors that influence the value of the HBE (such as feedstock cost), and thus the HBE price fluctuates. Based on historical data, Bio4A [49] concludes that the HBE price has risen from € 4.50 in 2014 (when HBEs were referred to as bio tickets) to €10 per HBE on average in 2019.

4.4 Environmental characteristics

Biofuels to be included in meeting the renewable energy targets must meet the sustainability criteria under the EU Directive to produce biofuels and liquid biomass. Sustainable means that production of biofuels respects biodiversity rich areas, primary forests, peatlands and contributes to reducing greenhouse gas emissions [47].

Biomass is produced and used in many countries other than the Netherlands, and international agreements on sustainable production are needed. The Netherlands is collaborating with other countries to develop policies for long-term biofuel and liquid biomass production. The Ministry of Infrastructure and Water Management is a member of the Global Bio-Energy Partnership (GBEP)[11].

The G8 +5 (Brazil, China, India, Mexico, and South Africa) included the launch of the GBEP in their Gleneagles Plan of Action (July 2005) to support wider, cost-effective biomass and biofuels deployment, particularly in developing countries where biomass use is prevalent. Other countries, including the Netherlands, have since joined GBEP. GBEP has created bioenergy sustainability indicators for national voluntary use. Several GBEP partners are currently testing these indicators, and their use is being promoted in other countries.

Types of feedstock

Fuels produced from the approved feedstocks listed in Annex IX of the RED II will count twice as much toward the 14% target. List A of the Annex contains a variety of lignocellulosic energy crops, wastes, and residues that can be used in any amount. List B, on the other hand, which includes used cooking oil (UCO) and animal fats, is limited to contributing 1.7% of the overall target. Only advanced biofuels derived from feedstocks listed in Annex IX list A contribute to the 0.5 and 3.5% advanced biofuel targets for 2020 and 2030, respectively, and are double-counted towards the 3.5 percent transportation sub-target [48].

The Netherlands' introduction of the RED II would necessitate significant changes to its biofuels program, which has resulted in negligible quantities of fuels derived from lignocellulosic wastes and residues thus far. The Netherlands currently supports its 2020 RED goal with a biofuel quota of 16.4% total renewable energy (including multipliers) and a 1% advanced fuels sub-target. Crop-based fuels' contribution will be capped at 5% in 2020, according to the regulation. Fuel suppliers are required to comply with these regulations, and non-compliance is subject to a variable penalty [48]. While the Netherlands already gets about 72% of its renewable energy transportation from waste, it mostly comes from UCO and animal fats, which are capped under RED II Annex IX List B. Furthermore, domestic raw materials account for less than 10% of the biofuels consumed in the country. There is potential to increase the contribution of domestic resources to meet the Netherlands' advanced biofuels targets as the government evaluates the scale and design of its policies [48].

Environmental Impact

The Netherlands published a National Climate Agreement in 2019 that includes a long-term commitment to sustainable biofuels and deep decarbonization. The agreement lays out a bold plan to reduce emissions to 49% below 1990 levels by 2030, allowing the country to meet its Paris Climate Accord commitment. To achieve this, the government plans to increase the amount of renewable energy used in electricity production to 70%, as well as provide an additional 0.64 MtoE (27 PJ) of renewable energy from advanced biofuels to the road transportation sector [48].

[11] The Global Bioenergy Partnership (GBEP) is a global collaboration of governments, international organizations, and businesses to advance the sustainable use of bioenergy.

This additional renewable energy for transportation must come from sustainable wastes and residues, in addition to separate contributions for electromobility and crop derived fuels, according to the agreement.

5 Norwegian and Swedish electricity quota

The electricity certificate program is a market-based assistance program. Renewable energy producers receive one certificate per MWh of electricity produced for a period of up to 15 years under this system. The electricity certificate scheme is technology-neutral, which means that all forms of renewable electricity production, including hydropower, wind power, and bioenergy, are eligible for certificates.

5.1 General and design characteristics

5.1.1 Aim of the scheme

The main aim of the Norwegian and Swedish electricity quota is to increase the renewable electricity production by 28.4 TWh in 2020, divided by two sub quota for both countries: 13.2 TWh for Norwegian consumers and 15.2 TWh for Swedish consumers. The scheme is a support instrument for both the deployment of production capacity and the use of renewable electricity by consumers. Sweden had a target of an additional 18 TWh of electricity generated in 2030 compared to 2020, but as they expect to reach this target already before 2022, they determined to shorten the duration of the quota obligation until 2035 [50] (Not visualized yet in Figure 14).

Figure 14: The development of the Norwegian and Swedish quota levels over time [51]

5.1.2 Description of the scheme

Electricity certificates for a specific percentage of electricity consumption (quota) are required of all electricity suppliers and certain categories of end-users. This percentage will gradually increase each year until 2020, when it will be gradually reduced until 2035. In Norway, the scheme will be phased out in 2036.

The Norwegian and Swedish governments' quota obligations create a demand for electricity certificates, causing them to gain value. As a result, the government determines how many certificates must be purchased, but the market determines how much they cost and which projects are carried out. In addition to their earnings from electricity sales, renewable energy producers profit from the sale of electricity certificates. The revenue from the electricity certificates is intended to make the development of new renewable energy-based electricity production more profitable. Electricity bills from end-users contribute to this.

Norway and Sweden have a bilateral agreement that governs the electricity certificate market, while both countries have their own register in which certificates can be cancelled and traded nationally. The RED (2009/28/EC) provides a mechanism for cooperation between the two countries. The possibility of meeting a quota obligation in Sweden by purchasing Norwegian electricity certificates, and vice versa, was a prerequisite for the establishment of the joint Norwegian-Swedish market.

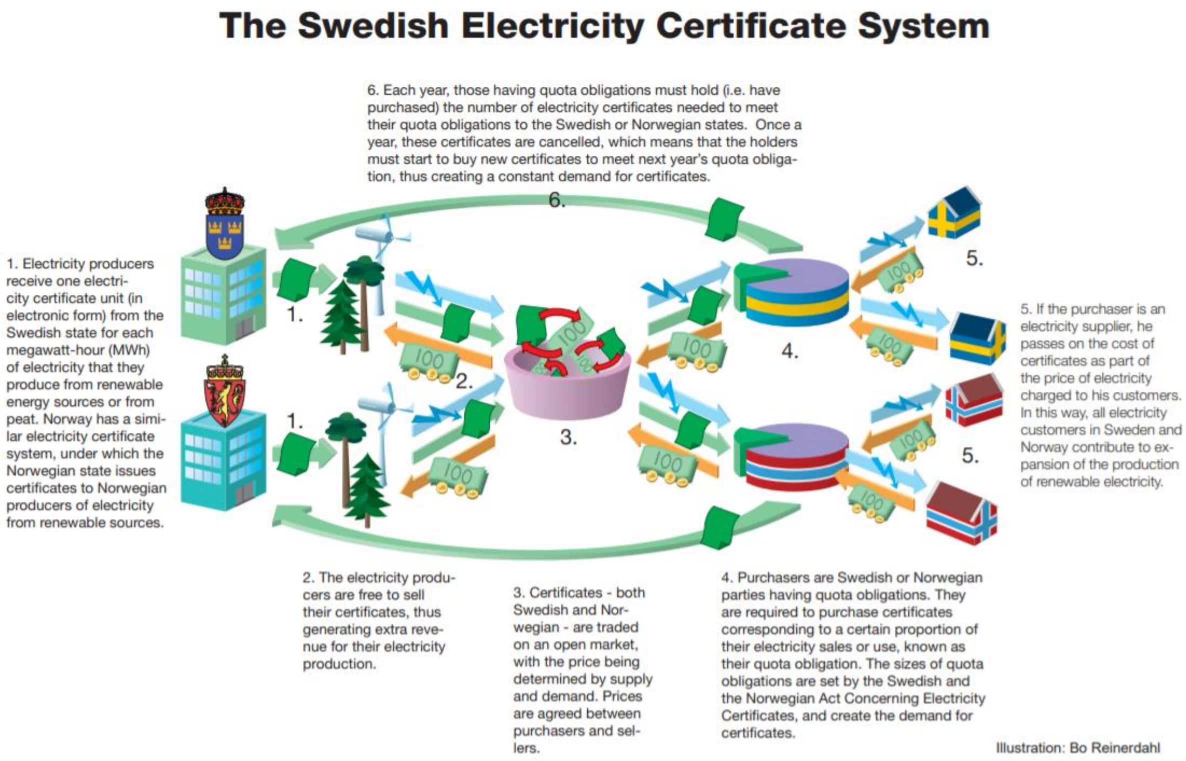


Figure 15: The Norwegian-Swedish electricity certificate system (Source: Swedish Energy Agency http://www.energimyndigheten.se/en/sustainability/the-electricity-certificate-system/)

5.1.3 Introduction of the scheme

Sweden and Norway have had a common market for electricity certificates since January 1, 2012. It is based on Sweden's electricity certificate market, which has existed since 2003. The common electricity certificate market is due to continue until the end of 2035.

The electricity certificate market aims to increase renewable electricity production by 26.4 TWh in both countries by the end of 2020. Sweden and Norway are each responsible for half of the increase, but the market will determine where and when the new production will occur [52].

Council

The Council for the Electricity Certificate System was established in accordance with Article 11 of Sweden and Norway's Agreement on a Common Market for Electricity Certificates, which was signed on June 29, 2011. Representatives from the Norwegian Ministry of Petroleum and Energy, as well as the Swedish Ministry of Enterprise, Energy, and Communications, make up the Council. The Council's job is to make planning and implementation of progress reviews easier, among other things [52].

5.1.4 Obligated parties and accepted technologies

The obligated parties differ slightly between Norway and Sweden, as the quota system is regulated in both countries by its national laws (which differ slightly). In general the following parties are obligated to cancel certificates for a share of their electricity consumption:

- Electricity suppliers;
- Consumers who produce electricity themselves;
- Consumers who purchase electricity themselves through bilateral agreements or the spot market.

The only difference between the countries is that in Sweden only consumers that produce more than 60 MWh per year and have installed capacity over 50 kW are part of the quota obligation, instead of all consumers in Norway [53].

As stated, the quota is technology neutral towards renewable electricity sources defined by the RED-II, which means that no renewable technologies are excluded, categorised or double-counted. The technologies should be deployed in the geographical area of Norway and Sweden, but production capacity in Sweden can be used to comply to the targets in Norway and vice versa. Thereby, only new installations or increased production capacities of existing installations can be approved for the quota scheme. In Sweden the system started in 2003 and Norway joined in 2012, which means that installations before those years could not be approved. The installations are receiving certificates until 15 years after their commissioning date. It is announced that the issuing of certificates will stop after 2035 and the system will close for new installations at 1 January 2022 [50]. The reason is that due to technological and market advancements, no support is required anymore.

5.2 Legislative characteristics

5.2.1 Combination with other regulations and support schemes

In 2011, an agreement between Norway and Sweden was made to establish a common market for renewable electricity support certificates. Despite being one market, each country has their own national acts and regulations to embed the certificate system into the regulatory regime. In Norway, the system is embedded in the Electricity Certificate Act and Electricity Certificate regulations and in Sweden, where a quota obligation was already used since 2003 to support renewable electricity, the system is embedded in the Electricity Certificate Act, Electricity Certificate Regulation and the Swedish Energy Agency's Regulation STEMFS regarding electricity certificates[12].

Electricity certificates that can be used to comply with the electricity quota should not be confused with the Guarantees of Origin scheme for electricity deployed in Europe. New renewable electricity generation capacities can produce electricity that obtains two certificates for each MWh of produced electricity: one Guarantee of Origin and one support certificate. Only the support certificate can be used by consumers to comply to the quota, to contribute its share of support for the deployment of renewables and the Guarantee of Origin can be used to prove the renewable Origin of consumed electricity.

5.2.2 International interactions

The electricity certificates cannot be exported or used in regions outside Norway and Sweden, as the market is a bilateral agreement between Norway and Sweden. From 2012 until 2019, significantly more certificates were issued in Sweden (e.g. 17.9 TWh) compared to Norway (e.g. 7.7 TWh) [51]. Therefore, it can be assumed that Norwegian consumers use a share of the Swedish produced certificates to fulfil the quota. Apparently, in Sweden it was possibly more cost effective to deploy additional renewable production than in Norway.

5.2.3 Reliability of the scheme

The schemes reliability is governed by the NVE and Swedish Energy Agency[13]. To the knowledge of the authors, no issues with regards to reliability or fraud have been faced.

[12] The Electricity Certificate Acts and Regulations are the translation of the bilateral agreement of Norway and Sweden in their national legislations. STEMFS is the Swedish national regulation to provide consumers with information and statistics related to the energy sector.

[13] Both the NVE and Swedish Energy Agency are directorates of the national ministries in Norway and Sweden responsible for the energy sector

5.3 Economic characteristics

5.3.1 Price effects of the quota certificates

The quota certificates can be traded via bilateral agreements or via brokers. During trade, two types of contracts are used: forward contracts (agreement for one or multiple moments in the future) and spot contracts (trade is done directly). Two type of prices for traded quota certificates are regularly published: the spot price and the register price. The spot price is the average price agreed in spot contracts at a certain moment, so the prices in trades where the price and trade is done at the same time. While the register price is the average price paid for the transferred certificates at a certain moment, which is the average price of exchanged certificates partly determined by spot contracts but these also include prices that were agreed some time ago in forward contracts (and therefore the register price is not perceived as the actual market price at a given time). It is unknown what share of quota certificates is traded by brokers, but market reports indicate that from the quota certificates traded by brokers, around 20-25% of the quota certificates is traded via spot contracts, 30-35% of the quota certificates is traded by forward contracts in the same year, around 30% is traded by forward contracts in the next year and 15-20% of the quota certificates are traded in forward contracts for the period thereafter [53] [51]. This means that most contracts are made for relatively short timeframes (<1 or 2 years).

The register prices of quota certificates in the Norwegian and Swedish registers (NECS and Cesar) are shown in Figure 16. It is visible that the prices in the registers are influencing each other, this underlines the statement that there can be spoken of one common market. The difference in NOK and SEK is also responsible for small price differences in both registries, however both currencies generally had comparable value during the last decade.

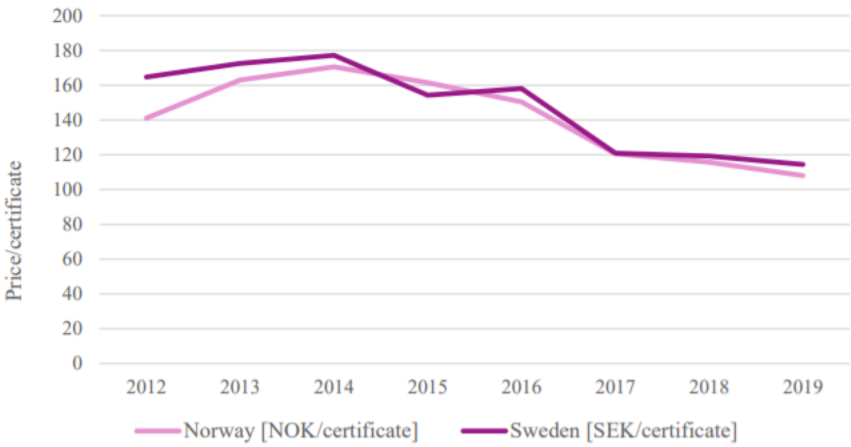


Figure 16: Average weighted register prices [51]

The spot prices in the period between 2021 and 2019 were quite comparable to the register prices (see Figure 17, note that these are monthly averages and in Figure 16 yearly averages are visualised). Except from 2017 and 2019, when the spot prices were significantly lower than the register price. Also, Figure 17 illustrates that there have been fluctuations in price during the years and months that the scheme was operated.

Figure 17: Average monthly spot prices of the electricity quota certificates [51]

5.3.2 Schemes contribution to deployment

In 2019, more than 34 TWh of quota certificates were issued, which was already 6 TWh more than the target that was set for 2020. In Norway and Sweden, different technologies were found to be most cost effective to be deployed as part of the scheme. In Sweden, most of the electricity contributing to the scheme was generated by wind turbines, contributing for more than three quarters of the total Swedish share of production under the scheme (see Figure 18). Furthermore, biomass and hydropower were used to obtain certificates.

Year	Biofuel and peat	Solar	Hydro	Wind	Total
2012	174 (773)	0.4 (1)	2 (11)	566 (2 061)	742 (2 846)
2013	742 (986)	2 (7)	76 (424)	3 248 (3 899)	4 068 (5 316)
2014	881 (1435)	9 (18)	454 (534)	4 699 (6 584)	6 043 (8 571)
2015	1367 (2088)	23 (42)	694 (658)	8 577 (8 852)	10 661 (11 640)
2016	1 967 (2 855)	43 (76)	618 (786)	9 080 (10 626)	11 708 (14 343)
2017	2 230 (2 903)	72 (120)	760 (824)	10 747 (11 229)	13 809 (15 076)
2018	2 358 (4 084)	118 (180)	759 (939)	10 668 (13 862)	13 903 (19 065)
2019	3 336 (4 588)	179 (300)	1 007 (1 116)	13 424 (17 898)	17 947 (23 903)

Figure 18: Actual renewable electricity production per source and the expected production (in brackets) under the quota scheme in Sweden [51]

In the overall electricity mix of Sweden, the increased share of wind production is also visible, being responsible for 11% of the total generated electricity in 2017 (see Figure 19). The contribution of hydropower is very limited compared to the massive amount of hydropower that was already generated in Sweden before. The effect of biofuel and heat is part of (industrial) CHP or, like solar, not made visible, because electricity generation for own use is not included in the graph.

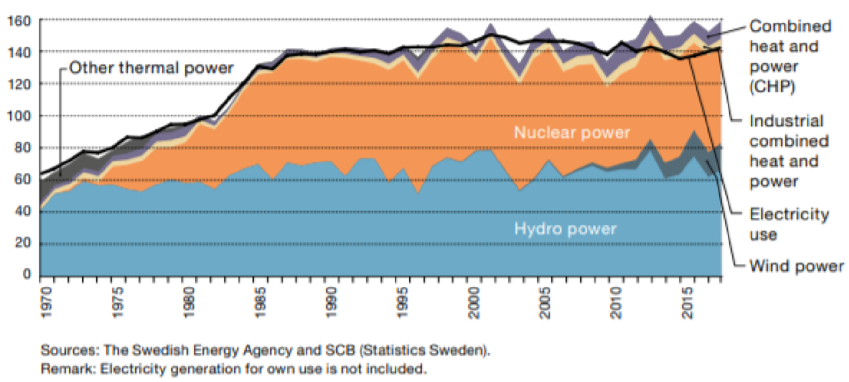


Figure 19: Electricity use and electricity generation per type of power in Sweden 1970-2017, TWh [54]

In Norway, almost the full share of the renewable production contributing to the scheme was filled in by hydropower until 2016. After 2016, the share of wind power increased significantly. Biomass and solar electricity was barely used to contribute to the scheme. Thereby, it should be taken into account that the circumstances of solar energy are not favourable in Scandinavia.

Year	Biofuel and peat	Solar	Hydro	Wind	Total
2012			40 (342)	3 (16)	42 (358)
2013			397 (729)	39 (185)	436 (920)
2014			717 (1361)	218 (374)	934 (1741)
2015			1712 (1854)	344 (391)	2055 (2252)
2016		0.3 (1)	2052 (3002)	358 (434)	2411 (3435)
2017	1 (0)	2 (5)	3 116 (3 686)	695 (1 540)	3 812 (5 232)
2018	2 (0)	4 (9)	3 692 (4 604))	1 940 (3 130)	5 636 (7 744)
2019	3 (0)	9 (11)	4 201 (5 434)	3 486 (5 023)	7 696 (10 468)

Figure 20: Actual renewable electricity production per source and the expected production (in brackets) under the quota scheme in Norway [51]

In Norway, almost all electricity consumption was already renewable before the electricity certificate system started in 2012, as the major share of electricity was produced by hydropower. The power surplus that Norway used to have, became apparent when the market was deregulated in 1998. The scheme helped to increase the power surplus of electricity again, by the additional support for renewable hydro- and wind power. Moreover, the electricity system became less dependent on the levels in the water reservoirs which depend on low temperatures in the winter. Lastly, the scheme was proposed to add value by the export of electricity.

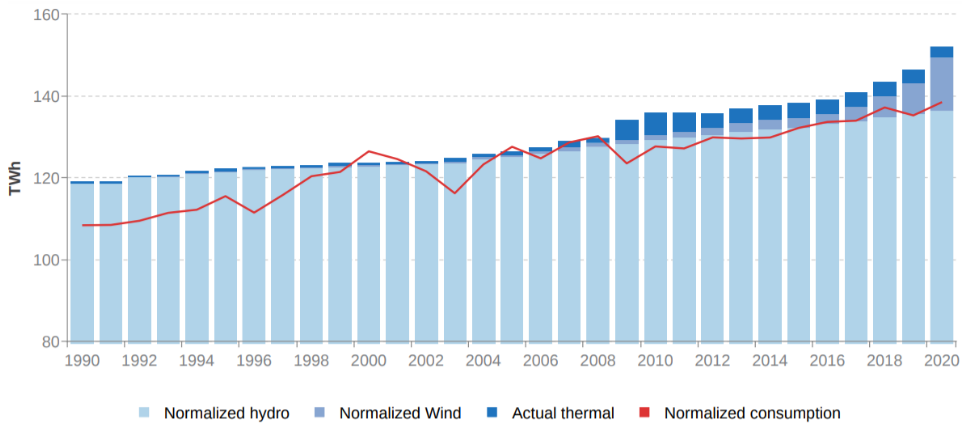


Figure 21: Normalized production and consumption of electricity in Norway 1990-2020, TWh [55]

5.3.3 Finance of the scheme

The costs of the new renewable generation installations were fully covered by the certificate prices, paid by consumers. In Sweden, this resulted in relatively higher effect of the electricity quota on the electricity price than in Norway. This is because generally Sweden had higher targets than Norway (certificates had to be purchased for 30.1% of the total electricity in Sweden compared to 17.1% of the total electricity in Norway), resulting in relatively more certificates that had to be purchased by consumers in Sweden. In Sweden, the price of certificates contributed with 2.9 öre/kWh[14] at the start and was around 3.5 öre/kWh during the last years, on an electricity price of around 185 öre/kWh for households (see Figure 22 for the electricity prices in Sweden).

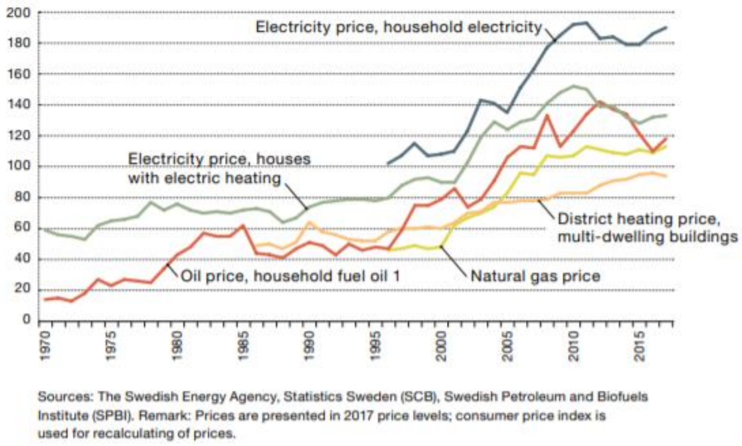


Figure 22: Energy prices for households and facilities in Sweden 1970-2017, incl. taxes and VAT, öre/kWh [54]

In Norway, the contribution of the certificate price to the electricity costs were 0.4 øre/kWh at the start of the scheme and around 1.8 øre/kWh during the last years. The electricity price paid by end-users in Norway was around 100 øre/kWh. The share of the certificate prices as part of the total price paid for electricity in Norway is shown in Figure 23.

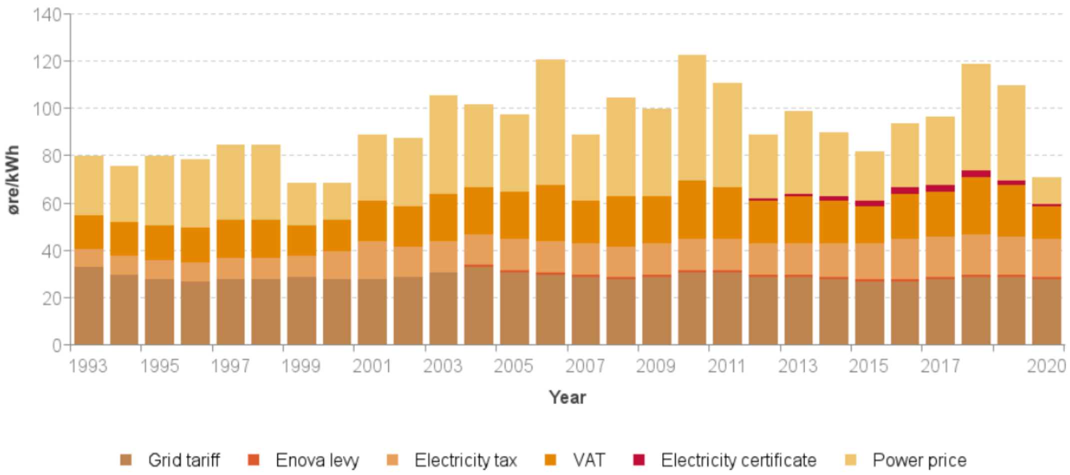


Figure 23: End-user electricity prices in Norway, incl. taxes and VAT [56]

[14] An öre is 1/100 SEC and an øre is 1/100 NOK

5.4 Environmental characteristics

Contribution to carbon reductions

The main purpose of the renewable electricity quota is to stimulate renewable electricity generation. Since the electricity sectors in Norway and Sweden are not contributing a lot to the carbon emissions of the country (due to the large shares of hydro and nuclear capacities), adding renewable capacities will not have that much effects on reducing carbon emissions. On the other hand, the renewable quota will add renewable capacities for electrification of other sectors with renewable electricity and reduce the nuclear waste.

6 Comparison of the assessed schemes

In the previous chapter all four schemes are described based on pre-determined characteristics. Some of the important characteristics discussed in previous chapters are compactly summarized in Table 5.

Table 5: Summary of the characteristics of the assessed admixing schemes

Characteristics		Voluntary schemes		Mandatory schemes	
		RES-E GO's by CertiQ	**Green gas GO's by Vertogas**	**Dutch fuel blending obligation**	**Norwegian-Swedish electricity quota**
General design and purpose	**Main purpose**	Tracking the origin of electricity	Tracking the origin of biomethane	Support use of biofuels	Support new renewable production
	Sub-targets	None	None	Per category of resources	Per country
Legislative	**Combination with other support**	SDE++ (revenues PV and wind GOs incl.)	SDE++ (revenues GOs excl.)	No	GOs can be sold separately
	International trade	Yes	Limited (currently)	No	Limited (only N&SE)
	Reliability issues	'Greenwashing'	Cheat with biomass	Cheat with biomass	No known issues
Economic	**Certificate price level***	0.04 – 0.18	0.38 – 1.15	0.59 – 0.68	0.27 – 0.29
	Price transparency	Moderate	Low	Low	Highest
	Effect certificate price on unprofitable gap	Low	Low	High	High
	Share additional renewables in sector	1.5% in 2003 to 18.3% in 2019	0.03% in 2010 to 0.34% in 2019	2% in 2007 to 12.5% in 2019	5.9% in 2011 to 13.5% in 2019**
Environmental	**CO_2 reductions tracked**	No	Yes	Yes	No

* Price level (in 2019) as ratio of the certificate price divided by the price of the physical energy (avg. market price excl. taxes)

** The numbers contain the share of cancelled certificates as part of the total electricity generation in Norway and Sweden. Obviously, the total share of renewables in the Norwegian and Swedish electricity sectors is way larger than these numbers

A more comprehensively comparison of the schemes will be done by addressing the following topics: the guarantee of reliability, the tradability of certificates, the allowance of cumulation in support schemes, effects on investments and deployment, the introduction of the schemes and the perceived risks. It is chosen to dive into these topics, as they are expected to be relevant with regard to learn from, as it comes to the development of hydrogen admixing policies.

6.1 Guarantee of reliability

Issues with regards to scheme reliability

Taking into account the assessed schemes, the following issues were found that are perceived most vulnerable to the reliability of (end-)users on the schemes:

- The experiences of international exchange between electricity GOs learned that the system loses its credibility among users when too large differences exist between the administrative claims and the physical reality (around 30% of electricity use was claimed to be green in 2012 while in reality while in reality 10% of electricity was produced by renewable sources in the Netherlands). Thereby, when there are a lot of countries where demand for certificates is low, then it could even harm the deployment in other countries with high demand, as they have the option to buy certificates instead of deploying new capacities.
  In addition to this, the difference in use of renewable electricity in European countries caused misperceptions about the electricity GO scheme. For the Netherlands were barely renewable electricity was produced before the CertiQ scheme started, all renewable electricity that was produced would be additional. Therefore, consumers perceived to contribute to the deployment of renewable electricity capacity when they agreed green power contracts. However, in a country such as Norway all electricity produced was ‘green’ already. Therefore, there was no urgency for Norwegians to focus on buying green electricity and the certificates were exported to countries such as the Netherlands, leaving the money in the pockets of the existing Norwegian utilities instead of the contribution Dutch consumers wanted to make towards deployment of new renewable energy capacities.
- Based on the experiences with biomass, it can be concluded that this source is more complex to handle than others, when it comes to support schemes and certification. First, this is due to the limited availability of it, and the diversity of applications were biomass is used (e.g. food production and other natural cycles). Several issues are seen, such as deforestation to burn wood in electricity plants and importing soja to comply to the biofuel targets. Secondly, a lot of types of biomass exist with their own characteristics. Sometimes, for example with the digestion to biogas, blends of multiple biomass sources are used. This makes it difficult to check and test if there are not any other non-renewable sources admixed in the biomass blends.

Measures with regards to scheme reliability

All the schemes take measures to guarantee their reliability. Some general measures are taken by most of the schemes. Firstly, all schemes have strict criteria for the application of installations and reporting and measurements that should be done to prove how volumes are produced. Secondly, the certification schemes are all embedded in national and/or European laws. Thirdly, the electricity and gas certification schemes are in close collaboration with the grid operators to obtain data about the injected volumes into the grid. Furthermore, some less obvious measures, taken consciously or not, should be elaborated further upon:

- With regards to the large share of imported electricity certificates, a significant change occurred after a lot of attention was paid by the media towards how the certificate market worked. After 2012, a sharp increase of the domestic certificate prices was seen compared to the imported certificates. Moreover, energy suppliers started to differentiate contract offers of 'green electricity' and 'domestic green electricity'. Also, difference in value increased more and more between the different technologies used to produce renewable electricity. The certificates of wind and solar electricity were valued higher than the biomass certificates, and even between the types of biomass certificates (e.g. co-fired, NTA8080 certified) price differences existed. This suggests that the more consumers are aware of the information provided by the certificates, the more they value the type of certificate that they found reliable in terms of contributing to 'green' the electricity sector. In the mandatory scheme of Norway and Sweden, no information was found that such differences in certificate prices exist per type of electricity generation. In the fuel blending obligation, the perceived reliability of the contribution of biofuels to sustainability is enforced by differentiation of three types of HBE's and attaching different weights to them in contribution to the targets. Hence, in the voluntary systems users have more impact in valuing the systems reliability than in the mandatory schemes.
- The issues with the sustainability of the biomass are experienced hard to tackle. Both the Vertogas and fuel blending scheme try to increase the transparency through the whole biomass chain by adding labels to their certificates. One important label is the NTA8080/Better Biomass label, created by the NEN to prove that biomass used for energy purposes is handled in line with the international and European standards. In the Vertogas scheme, biomass requires this label in order to be certified and 80% of the biomass used in the fuel blending scheme is NTA8080 certified (the other 20% with ISCC EU label). Furthermore, other labels are shown on the certificate to prove sustainable agriculture and other information of the resources and processes throughout the chain. Besides national and international roadmaps being created for the use of biomass in different sectors, an EU-wide database for biofuels is in development and measures are taken to improve the traceability and supervision through the chains. In 2020, multiple parties in the Dutch government expressed their concerns on the fraud in the fuel blending system, and stated that more measures to ensure the reliability and to reduce the negative side effects should be taken, before the target could be increased [57].

Guarantee of reliability is important for both voluntary and mandatory schemes. However, a difference is that voluntary schemes will de-valuated and used less when the reliability of the scheme is concerned, while for mandatory schemes this is not an option. Furthermore, the more complex the (international) value chains of the resources and its applications for other sector, the harder the system reliability can be guaranteed and the bigger the risks on negative side effects.

6.2 Tradability of certificates

Differences with regards to the exchange of certificates between the schemes are seen in the international connections of the markets, the transparency in the markets and the agreements that are used to exchange the certificates.

With regards to the international exchange of certificates, large differences are seen in the demand for GO's among countries for both electricity and biomethane GO's. For electricity, this is mainly the case due to that some countries already produce a lot of renewable electricity and therefore consumers perceive to consume renewable electricity already, but meanwhile another country is purchasing the certificates. For biomethane, the import and export is mainly determined by the difference between legislations based on stimulating the production or the use of biomethane. The disadvantage of both cases is that half of the countries state to be good due to its high levels of renewable production and the others due to high levels of renewable consumption. The advantages of opening the market are that there are more options for buyers and sellers to trade the certificates and that it stimulates competition to deploy the most cost effective technologies at the most cost effective locations. However, for both voluntary schemes it is seen that additional national support schemes (mostly Feed-In-Tariffs or Feed-In-Premiums) have larger contribution to the deployment than the price of certificates, therefore these international markets do not determine where capacities will be deployed. Moreover, it can be argued that national subsidies on production 'leak away' to the countries that only stimulate consumption. For example when Switzerland purchases the Dutch Vertogas certificates in order to green its gas consumption, they only have to pay the certificate price (contributing ~13% of the production costs, while ~65% of the production costs were covered by the SDE subsidy financed by the Dutch tax payers). On the contrary, the Norwegian-Swedish electricity quota was effective in deploying only the most cost effective technologies in the most cost effective regions. In this system, the actual energy users in both countries are forced to support deployment of new renewable capacities, independent in which of both countries the actual production capacity would have been deployed.

Besides, differences are seen in the transparency of the certificate prices in the different schemes. The Norwegian-Swedish electricity quota publishes register prices and spot prices to inform the market about its developments, while from the other schemes no price data is publicly available. About the electricity GO's relatively more information is known than the Vertogas certificate and HBE prices, as these last two schemes are dominated by relatively few players. For the Dutch electricity GOs, it is seen that more and more are traded via Power Purchase Agreements. Often, the consumers of the certificates are already known before the project is realised, reducing the risks of the high capital investments. It is noticeable that in the Norwegian-Swedish certificate market, most trades are made on the relatively shorter terms (<2 years). Possibly this has to do with the differences electricity mix between Norwegian, Sweden and the Netherlands. Norwegian and Sweden have large shares of flexible hydropower compared to the flexible gas power plants that will produce in the Netherlands when the output of wind and solar electricity generation is low. As the marginal costs of hydropower are way lower than those of natural gas powered plants, less price fluctuations can be expected in the Norwegian and Swedish electricity market compared to the Dutch electricity market in a future with high penetration of intermittent solar and wind generation. The more the uncertainty in the business cases and price developments of the physical energy markets, the more it is expected that long term contracts between suppliers and customers will be favoured.

6.3 Allowance of cumulation in support schemes

Comparing the four schemes, they all differ in how they handle the cumulation of support. Firstly, both Dutch voluntary schemes for RES-E electricity and biomethane admixing have the criteria than only certified production can receive support of the SDE++ subsidy. However, the way the revenues of the GO's are incorporated differs. Since 2020, the expected revenues of GO's received by solar PV and wind electricity generation are incorporated in the expected revenues of the electricity sold. According to PBL, who calculates the expected tariffs of the SDE++, only revenues of GO's are taken into account when 1) those markets are assumed to be liquid enough and 2) the GO price exceeds 3 euro/MWh [58]. Therefore, the average prices of certificates for electricity produced by biomass are not high enough and as the prices for Vertogas certificates are expected to be between 5 MWh and 15 MWh, the market is assumed not to be liquid enough to incorporate the GO revenues. This means that in theory the revenues for subsidies could fill the unprofitable gap and the GO's revenues are additional profits for the producers of biomethane or electricity from biomass. However, it should be stated that the SDE++ application opens in different phases (based on subsidy intensity per reduced CO_2

emissions) and limited budget is available which means that only the cheapest CO_2 reduction technologies could receive the subsidies (as generally the budget is already spent before the last round starts). Therefore, it is expected that in practice GO revenues for other technologies than solar PV and wind could be taken into account in the application for the SDE++ to increase the chance to obtain the subsidy. Especially for biomethane production, as these technologies are considered as the more expensive ones in the SDE-Ranking, it could be expected that the GO revenues are required to obtain the subsidy for most biomethane production technologies.

Secondly, also the assessed mandatory schemes differ in the way they allow cumulation of support. For the Dutch fuel blending scheme, only non-subsidized fuels can be used to receive HBE's. For example, only Vertogas certificates can be exchanged for HBE's when those GO's include the information that the biomethane was produced without receiving subsidies. The Norwegian-Swedish electricity quota works differently. Here, clear separation is made between certificates with tracking (e.g. GO's) and support (e.g. quota certificates) purposes are made. This means that renewable production facility applicated to the quota scheme could receive two certificates (one GO and one quota certificate) for every MWh produced. However, as the quota certificate market is (like the SDE++) competition based as well, the technology with the largest unprofitable gap that is required to fulfil the quota will determine the quota certificate price. This means that in a well-developed market, the GO revenues will decrease the quota certificate price and therefore will not lead to windfall profits or accumulation of support. In practice, the revenues of Norwegian electricity GO's are very low (around 0,2 euro/MWh) compared to quota certificate price (10,6-11,3 euro/MWh) and therefore will not have significant impact on the quota certificate market prices. The main difference in the way GO's are used in both cases is that for the fuel blending scheme, the Vertogas certificate acts as Proof of Sustainability (PoS) to prove that the feedstock (input) used as basis for the fuel is certified as sustainable (ISCC-EU, RSB EU RED and Better Biomass are also used as PoS for HBE's, the Better Biomass/NTA8080 principles are also incorporated in the Vertogas GO certificate) while the electricity GO in case of the Norwegian-Swedish electricity quota is used to prove the sustainable origin of the produced electricity (output).

6.4 Effects on investments and deployment

Starting with the Dutch voluntary schemes, it was seen that both CertiQ and Vertogas schemes have the main purpose to track and price the origin of the renewable energy. Both schemes are connected with the Dutch subsidy (the SDE++) that is used to stimulate renewable energy production technologies, as new production facilities have to be registered at the schemes in order to obtain the subsidy. Looking to the effects of the certificate prices and the SDE++ subsidy to close the unprofitable gap of these technologies, it can be concluded that the certificate price has a small share in contribution compared to the SDE++. Even until 2020 the GO revenues were formally not taken into account for the level of SDE subsidy that could be received. Thereafter, only revenues of solar PV and wind GO's are taken into account when determining the level of SDE subsidy for these technologies.

For renewable electricity and biomethane production technologies, the combinations of support differed in the effect on the actual deployment of these technologies in the Netherlands. Where the share of renewable electricity has increased from 1.5% in 2003 to 18.3% in 2019, the share of biomethane in the gas sector has increased from 0.03% in 2010 to 0.34% in 2019. On the one hand, it should be noted that the gas sector includes larger volumes (359 TWh in 2019, partly used to produce electricity) than the electricity sector (105 TWh in 2019) [59]. But mostly, it is due to that the SDE++ stimulates the most cost effective carbon reduction technologies and most renewable electricity production technologies score better in terms of euro's per ton of CO_2 reduced than biomethane production technologies. This means that the limited SDE budget is used to stimulate the most cost effective reduction technologies, instead of doing what should be done to reach carbon neutrality in all sectors before 2050. It is proposed by the Dutch Climate Agreement that 2 bcm or 70 PJ of biomethane should be produced in 2030 in order to reach the climate targets [60], which could become hard to reach if the effort done in this sector depends on the carbon reduction cost competitiveness compared to other sectors and technologies.

Compared to the voluntary schemes, the certificate prices in the assessed mandatory schemes had a significant impact on closing the unprofitable gap between the renewable and traditional energy use, as they were the only support mechanism to close the unprofitable gap. It was determined by law how much biofuels and additional renewable electricity should be used in each year in the assessed mandatory schemes, and both schemes reached their targets every year. Therefore, these schemes created certainty how much renewable energy is used in a specified sector. However, the notion should be made that fraud takes place at some biofuel producers in the Dutch fuel blending scheme. In 2020, a biodiesel producer with 100,000 tonnes of annual volumes was accused for fraud with certificates, meaning that potentially 38% of its 'proved' CO_2 reductions in 2015 and 27% in 2016 did not exist at all [61]. When such levels of fraud are proven, the credibility of the actual reductions and use of biofuels becomes in danger. On the other hand, the Swedish-Norwegian electricity quota proves that significant larger shares than the quota could be deployed. Where the share of deployment is more secure for mandatory quota's, the effect on the end-user energy bill is more uncertain. Assessing the expected impact of the quota certificates on the level of end-user prices, those were contributing with around 1.6-1.8% to the Norwegian-Swedish electricity prices and with 2.2-3% to the Dutch benzine and diesel prices in 2019.

6.5 The introduction of schemes

Management of the schemes

Even though all four schemes were implemented by governmental decisions, only two of them, corresponding to the voluntary schemes, were subsequently let to be managed by companies. The companies act on behalf of the Minister of Economic Affairs and manage the schemes. These companies are CertiQ which is a 100% subsidiary of Tennet, the Dutch electricity TSO, and Vertogas which is 100% subsidiary of Gasunie, the Dutch natural gas TSO.

On the other hand, the mandatory schemes, are managed by competent governmental authorities in each of their countries. The Dutch Emissions Authority (NEa) is the Dutch governmental agency overseeing and managing the Dutch fuel mandatory blending quota, while the Swedish-Norwegian Electricity Certificate Market is being managed by The Norwegian Water Resources and Energy Directorate and the Swedish Energy Agency.

Register system

All four schemes regulate and administer its participants intentions to obtain and trade certificates through a register platform. The participants of each scheme must register their activities in the following platforms:

- CertiQ for the Dutch Green Electricity admixing,
- Vertogas for the Dutch green gas admixing,
- Energy for Transport Registry (REV: *Register Energie voor Vervoer*) for the Dutch fuel mandatory blending quota,
- NECS and Cesar for the Swedish-Norwegian Electricity Certificate Market.

Councils

Both voluntary schemes, namely CertiQ and Vertogas, run a Partipants' council composed by traders and producers. The council's role is to represent the interests of the participants in the certification system, enabling the adjustment of policies to market trends and annual plans.

While the Dutch mandatory fuel blending scheme of The Energy for Transport compliance system does not appear to have established a council of the sorts, the NEa counts with The NEa Executive Board which is a non-departmental public body (NDPB), meaning that it performs government duties and reaches decisions independently of the political system.

The Swedish-Norwegian Electricity Certificate Market has a council consisting not of traders and producers' representatives but of delegates from the Norwegian Ministry of Petroleum and Energy and the Swedish Ministry of Enterprise, Energy and Communications.

Cross border operations

While the Dutch mandatory fuel scheme seems to not have a cross border trading objective (though the NEa collaborates closely with the International Carbon Action Partnership to enable knowledge exchange), the other systems operate internationally (where in the Norwegian-Swedish system the international trade is limited to two countries). Three out of the four schemes strive for an international market in which to trade their certificates. This is understandable since a larger market with more participants means more liquidity. Consequently, investments are made where the circumstances and profitability are the best. Furthermore, rather than having individual national markets, the goals of increased renewable electricity production can be achieved in a more cost-effective manner.

6.6 Perceived Risks

Evolving market

When assessing the risks involved with a voluntary scheme, such as the CertiQ and Vertogas, the major concern lies on the adoption and correct use of the system. The target parties must be appropriately incentivised in order for them to perceive and foresee the advantages of the scheme. Looking at the origin of the CertiQ scheme - which was to certify electricity suppliers for their renewable electricity in order to get a reduce energy tax rate - and the current GO handover, which are now the primary form to obtain subsidies for the generation of sustainable energy, makes its allocation mechanism of paramount importance. The outcome of mishandling which technologies and energy sources are eligible, dictates the adoption of endeavours that might not be the most aligned to particular goals – climate mitigation, cost-efficiency, use of resources, etc. Therefore, an adaptable and flexible scheme with a keen eye on both production and consumption is a mandate to properly develop and sustain energy certificate systems. This is acknowledged in CertiQ's 2020 annual report by stating that CertiQ must be able to respond flexibly to developments in the energy transition and think along with stakeholders about how the certification system can evolve to contribute to this transition, in addition to being able to generate reliable output in an efficient manner.

Introduction speed

One of the most significant risks in any scheme is its implementation speed. This is most evident when designing a mandatory scheme, where caution is advised to ensure that the scheme is not implemented too quickly in order to avoid catching the markets off guard. Due to a lack of current supply, a too rapid introduction could drive the price of the certificates to extremely high levels. As a result, efforts must be made to ensure that the market has enough time to develop. A stepwise introduction that allows a match between demand and supply could be one way to mitigate this effect.

Internationalization

Another potential risk comes in hand with the internationalization efforts. From the assessed schemes, most notorious is the case of CertiQ who wholeheartedly believes in a European level operation. This is reflected in CertiQ having a strategic board position in the AIB (Association of Issuing Bodies). The future outlook for the AIB is to operate "hubs" for the international trade of certificates of energy carriers – currently only applied to electricity – by developing a European standardized system for the certification of all energy carriers. The upside of such grasp is linked to a potential certification system in which all types of energy are 100% certified, ensuring complete transparency of their origin and use on a European scale. On the other hand, a cross-border trading operation might pose the risk of one country buying copious amounts of certificates and steering the market in such a way that leaves the originating country without certificates of its own. Moreover, the implementation of an international system creates the potential quandary of a leakage of subsides to other countries. It's possible that a country meets a significant portion of its renewable energy quota by purchasing a large number of certificates that were originally created with another country's subsidies, raising questions about the efficiency with which the latter country's tax-payers' money was allocated.

The mass-balancing approach is a unique feature of the certificates system in the gas market. This means that the exchange of certificates must be linked to the flows of the physical commodity for international trade and the use of certificates in the transportation sector. This method is intended to prevent double counting of renewable gas, but it also limits international trade because certificates can only be traded if they are linked to physical gas exchanges in the same network region [62]. A path to avoid this, might be reconsidering the need for the mass-balancing approach, and envision the chance of moving more strongly toward a book-and-claim approach for international renewable gas trade.

Trustworthiness

Not having a system developed under international standards might hinder the system's future development. The markets are aided by international standardisation of the sustainable character of the energy sources, as this increases market participants' trust in the value of the certificates [62].

The same can be said for having a certifying agency that is owned and operated by the government rather than a private company. The certification process is managed by market parties in some of the studied schemes, which may undermine consumer confidence in the certification. A mitigation for this risk might be to expand the role of government authorities in the certification process [62].

6.7 Main differences between mandatory and voluntary schemes

Based on the comparisons made in this chapter, the main differences between the assessed mandatory and voluntary schemes could be summarized.

Table 6: Major differences between the assessed voluntary and mandatory schemes

Voluntary schemes (SDE and GOs)	Mandatory schemes (quota obligation)
• Only the cheapest technologies are being deployed • Speed of deployment is based on the subsidy budget and costs of support • Major risk is that national subsidies will leak away towards other countries	• Only the cheapest technologies in a specific end-use sector are being deployed • Speed of deployment is pre-determined and costs are allocated directly to the users • Major risks are the introduction of the scheme and the preservation of reliability

7 Conclusions

In this study, experiences with multiple voluntary and mandatory admixing schemes in the energy sector were assessed in order to address lessons that can be taken into account for the development of a potential hydrogen admixing scheme. Four schemes were assessed, the CertiQ RES-E GO's and Vertogas biomethane GO's as voluntary schemes and the Dutch Fuel blending quota and the Norwegian-Swedish renewable electricity quota as mandatory schemes. Specifically, the general design, legislative, economic and environmental characteristics of those schemes were investigated. Thereafter, these schemes were compared based on their guarantee for reliability, tradability of certificates, allowance of cumulation in support, the effects on deployment, how the schemes are introduced and the perceived risks. Based on these assessments, the following lessons can be concluded:

Guarantee of reliability

- The reliability of the scheme could become endangered when too large differences exist between the administrative and physical reality. Moreover, certification systems intend to see things black and white: 'green products' and 'not green products', while sometimes consumers perceive differences in the level in which several products are green. When the right information is provided at the certificates, these differences in 'greenness' will be priced in voluntary systems since these prices depend on the willingness-to-pay of a consumer. Due to the mandatory consumption of certificates in the mandatory systems, it is experienced less likely that voluntary higher prices will be paid for certain products if cheaper options are available. When an undesirable amount of a typical technology would be established, we have seen in the Dutch fuel blending scheme that sub-quota targets can be used to deal with 'differences in greenness' between products.
- The more diverse the use applications of certain resources are and the more complex the value chains of those resources, the more complex it will be to prevent the system from fraud or outcompeting the use of the same resources in other sectors. Such issues are especially seen with biomass in the existing schemes, but similar issues could be expected with other resources that have one or multiple of these characteristics as well (e.g. scarce renewable electricity that is desired to be used in multiple sectors for decarbonization).

Tradability of certificates

- When schemes allow international trade, it should be considered that differences in the existence of the stimulated technologies (e.g. a lot of renewable electricity available in Norway) and the way technologies are stimulated among countries (e.g. countries that stimulate biomethane use buy certificates and countries that stimulate biomethane production export certificates) will have large impact on the import and export of certificates.
- It should be considered that the combination of production subsidies and voluntary GO schemes could lead to 'leakage' of national support financed by taxes that are used for carbon reductions claimed by other countries, when large shares of certificates are exported. The Norwegian-Swedish electricity quota is an example how the costs for support can be distributed proportionally between end-users.
- Generally, the more uncertainty is perceived in business cases or the commodity and certificate markets, the more likely it is that market players will prefer long term agreements for the purchase of renewable energy. This is especially seen in renewable electricity markets where stable fossil generation will be replaced by intermittent solar PV and wind generation.

Allowance in cumulation of support schemes

- In the voluntary schemes, the certificate revenues and subsidies could be accumulated. Since two years ago, only revenues for the wind and solar PV GO's are taken into account in determining the level of SDE++ subsidy.
- In the mandatory schemes, it was seen that production batches with subsidized 'resources' or 'inputs' could not be used to comply to the Dutch fuel blending quota. In the Norwegian-Swedish electricity quota scheme, it was seen that with a clear distinction in purpose between 'tracking' and 'support' certificates, revenues for both Quota Certificates and Guarantees of Origin could be obtained.

Effects on investments and deployment

- In both assessed voluntary schemes, the certificate prices have a small contribution in closing the unprofitable gap of the renewable energy production technologies. In these cases, the subsidy was the largest contributor to close the unprofitable gap of the business case. While in both mandatory schemes, the certificate prices had a large impact in closing the business case of additional renewable technologies.
- The SDE++ is effective in deployment for technologies that decrease carbon emissions against relatively low costs, as the subsidy is only used for the most cost effective carbon reduction technologies. For technologies, such as biomethane, which are considered essential but are relatively high in costs per reduced ton of CO_2, the deployment will be limited as long as more cost effective technologies are available. For decarbonization of specific sectors, both mandatory schemes that were assessed reached their goal of renewable energy use.

Introduction of schemes

- All four assessed schemes are legally embedded by the national governments. The voluntary schemes were implemented by companies 100% owned by the electricity and gas TSO's and the mandatory schemes were implemented by governmental authorities. Also, the voluntary systems use advising councils consisting of producers and consumers while the mandatory systems do not use such formalized councils to obtain input from the market parties.
- In three of the four assessed schemes, international trade of certificates has been developed at a later stage to increase the market liquidity and cost-effectiveness deployment of renewable energy capacities.

Perceived risks

- One of the major risks perceived in support schemes is the risk that subsidies paid by national taxes will leak away towards other countries. The assessed mandatory schemes had more clear geographical boundaries and did not include different national support schemes connected via international exchange of certificates. Moreover, the leakage risks are lower in the mandatory schemes, as 'the user pays'-principle was used.
- Especially for the mandatory schemes, the speed of introduction is a very important factor to consider. In both assessed schemes there were no reports that the level of the target rose faster than supply could be developed. Thereby, buy-out prices were used in both schemes.

Based on the comparisons between the assessed schemes, it could be concluded that the voluntary schemes assessed mainly focus on the deployment of the most cost effective carbon reduction technologies, while the mandatory schemes give more guidance and security that certain types of end-use applications or sectors could become decarbonized. The voluntary schemes have uncertainty in the actual deployment (depending on how much deployment can be supported with the determined budget), while the mandatory schemes have more uncertainty in the costs calculated towards the end-users. The advantage of ‘the user pays’-principle via the same mechanism, is that subsidies cannot ‘leak away’ due to differences in national policies. However, more careful attention should be paid to the introduction and the perceived reliability of the scheme.

With regards to the implementation of a hydrogen admixing scheme, all lessons concluded above are essential to take into account with regards to considerations of the systems design and desired purposes. Obviously, although analysed carefully, the experiences based on assessed energy admixing regimes are not fully interchangeable and comparable with the situation and purposes that a hydrogen admixing policy could have. The assessment is a case study, and the case of hydrogen will differ with its own characteristics. However, the generalized lessons can be taken as critical points of attention that should be used and analysed further when it comes to the question of how renewable hydrogen can be introduced to decarbonize the energy system.

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