Solar Energy needs Smart inverters

Market insight on flexible connected residential PV inverters

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FLEXIBLEPOWER ALLIANCE NETWORK

DELTA Energy & Environment

Contents

Background

More PV energy results in higher strain on energy grids

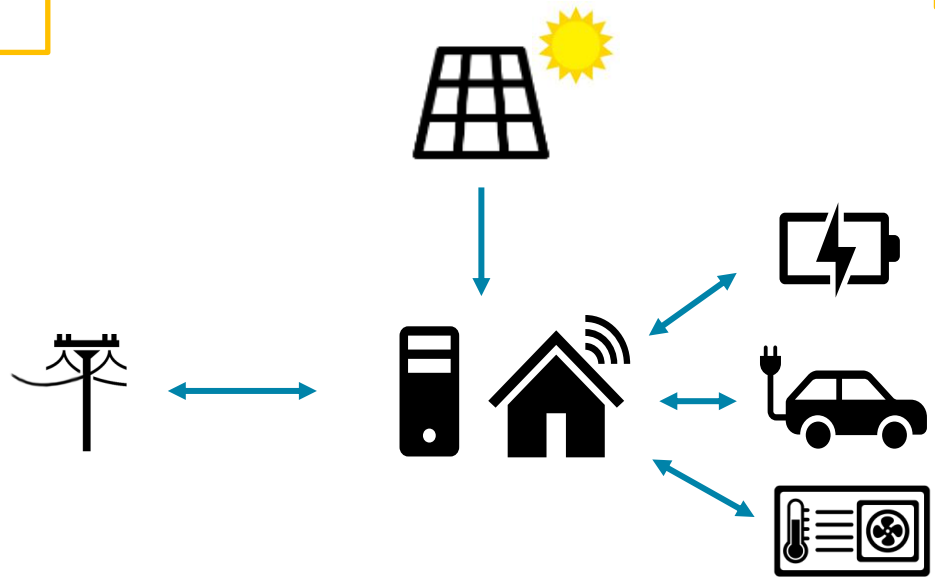
Phasing out net metering drives the need for optimizing PV generation

Need of insight in Flexibility options of PV inverters

Flexibility of the installed base of residential PV inverters

Flexibility of current offerings of residential PV inverters

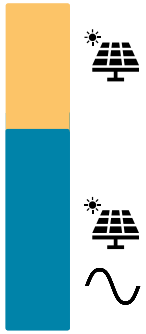
Report & Recommendations



Executive summary 1 / 2 – The trend

→ **From the residential PV inverters installed in 2019, over 50% (max 75%) have advanced functionality, allowing them to participate in Flexibility Services.**

In 2020, approximately 300000 residential PV inverters will be installed, representing ~ 1.2 GW.

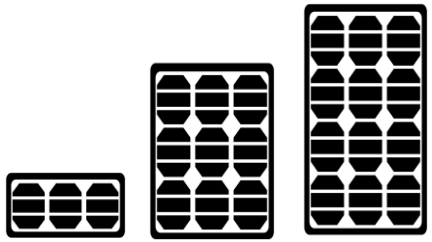


We estimate that 75000 – 129000 of the new inverters (25 – 43 %) are **not** well suited for flex energy. *

This represents ~ 0.3 – 0.5 GW.

We estimate that 171000 – 225000 of the new inverters (57 – 75 %) is suited for flex energy. *

This represents ~ 0.7 - 0.9 GW.



2015:	2020:	2023:
~91,000 ~0.4 GW	~300,000 ~1.4 GW	~400,000 ~1.9 GW

Annual sales:
The residential PV inverter market has grown rapidly, and annual sales will continue to grow.

- The installed base of residential PV systems in the Netherlands (NL) is ~0.98 million (2019).
- All new residential inverters available on the market have remote monitoring and diagnostics functionality.
- Products from the market leaders have modulating remote control functionality, enabling them to 'turn up' and 'turn down' the output of the PV system. These can be considered optimally suited for Energy Flexibility.
  - Since the market leaders hold 57 – 75 % of the market, a large proportion of inverters available on the market today are flex ready.
- In addition to inverters for *new* PV systems, the market for replacement PV inverters is growing.

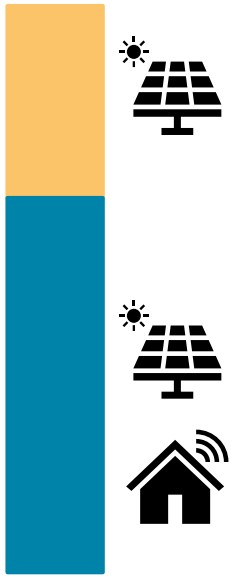
- Even when the inverter itself is Flex Ready, integrating Inverters into Smart Energy Services is not very scalable currently. Some important hurdles are: no standard for unlocking flexibility, additional extra hardware may be needed, and cloud services from manufacturers may be required.

* We consider inverters 'ready for Energy Flexibility Services' when they offer 'modulating remote control'. 25 – 43 % only offer monitoring or *on* | *off* functionality. See page 6

Executive summary 2 / 2 – The installed base

→ **By the end of 2019, we estimate 57-75% of installed residential PV inverters were ready for some form of Smart Energy Services, representing ± 2.2 - 2.9 GW of PV inverter capacity. ***

In 2019, there were approximately **976,000** residential PV inverters in the Netherlands, representing **~ 3.9 GW**. The average residential PV inverter size is around 4 kW



Approximately **244,000 – 420,000** residential inverters (25 - 43%) are not ready for smart energy services

This represents ~ **1.0 - 1.7 GW**

Approximately **556,000 – 732,000** (57 - 75%) residential inverters are ready for smart energy services

This represents **~ 2.2 – 2.9 GW**

- The market is crowded and competitive with at least 12 manufacturers active, with the top 7 brands taking about 95% the market share.
- The flexibility of inverters can play important roles:
  - Mitigating the end of net metering: Manage energy in the home and maximising self-consumption of PV generated electricity.
  - Support grid stability, prevent congestion and operate in VPPs.
- Manufacturers did not express many concerns regarding Flex and Residential PV
- Residential inverters are currently not used for flexibility services in NL.
- **The market** – rather than products – need to develop to enable this to happen.
- Awareness of Energy Flexibility in relation to residential PV is not high:
  - On 'what is Flex', and what is needed for Flex
  - On the benefits of Flex
  - Buyers tend to rely on recommendations of install parties and advisors. This offers good channels to bring forward the need for Flex.

* We consider inverters 'ready for some form of Smart Energy Services' when they offer at least monitoring and/or remote on|off functionality. See page 6

Introduction and scope

Introduction

Background

Flexiblepower Alliance Network (FAN) were interested to understand the current state of affairs and developments in the residential PV inverter market. In particular, FAN was keen to understand how ‘flex ready’ residential PV inverters currently are or may be in the future – and what role they can play in energy flexibility. The research focuses on the Netherlands.

FAN commissioned **Delta-EE** to carry out research into this area.

Aims

The scope of work was to characterise the residential PV inverter market in the Netherlands, and the flex readiness of PV inverters in the Netherlands.

The research aimed to:

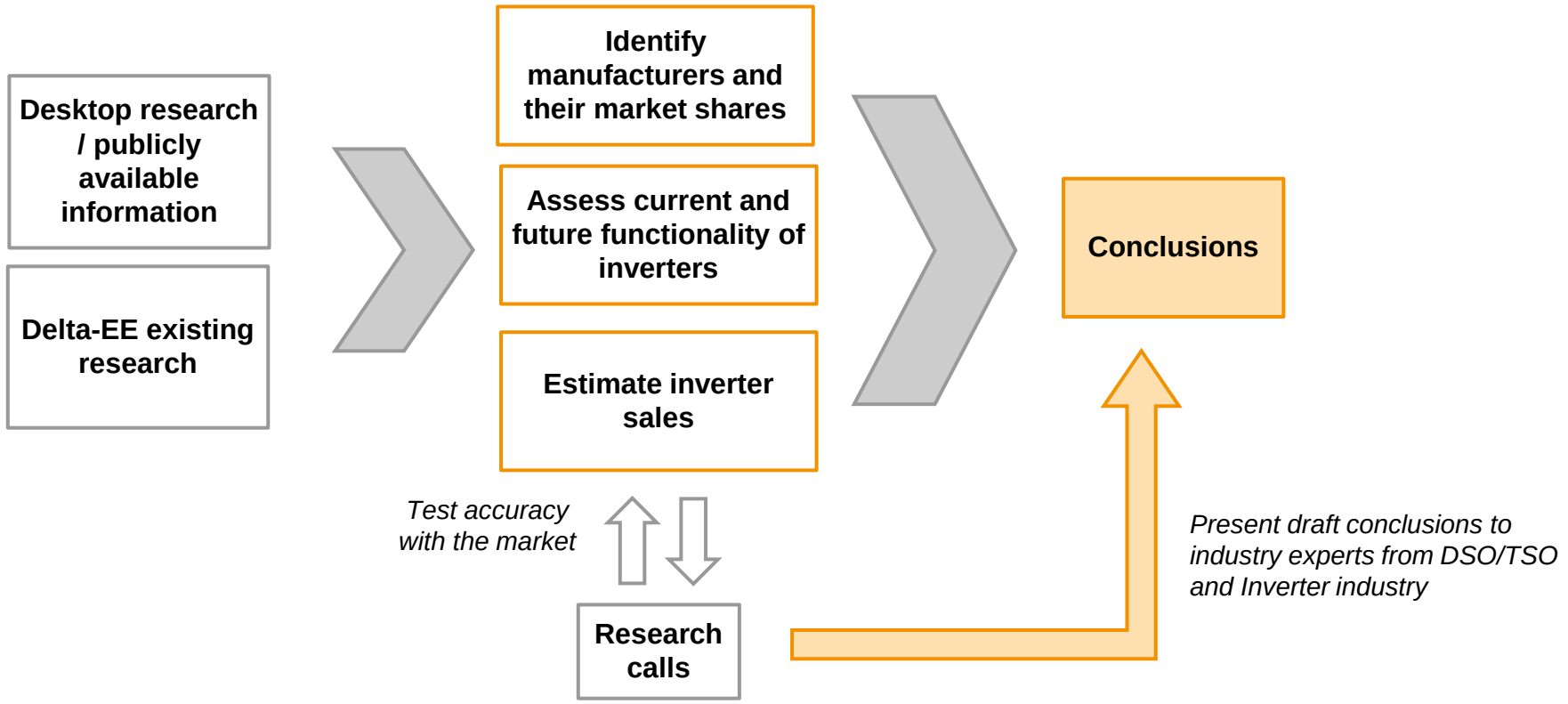
- **Identify key manufacturers and models** of residential PV inverters in the Netherlands and their **market shares**, and, where possible, annual sales between 2015-2020.
- **Characterise the functionality** of residential PV inverters in the Netherlands, including connectivity, remote control and **capability to unlock flexibility.**
- In the future, residential PV inverters could have a very important role to play in optimising energy in the home and in providing grid services. This report assesses the **capability of inverters** themselves to enable this and does not look at market conditions.

Methodology

The diagram below shows the approach taken by Delta-EE and FAN in this study and the different types of sources used to collect the information.

Research calls were held with manufacturers and industry experts.

Confidentiality: ALL information provided to Delta-EE by manufacturers on market shares and annual sales was provided in confidence for use by Delta-EE and FAN for the purpose of this research only.



Scope and definitions

Definitions

- A solar photovoltaic (PV) **inverter** is an electrical device which converts the electricity produced from the solar PV panel (in DC voltage) to electricity which can be used in the home or fed into the electricity grid (in AC form).
- Where solar PV is installed alongside a battery, there may be a separate battery inverter or a hybrid inverter. See the next page for an overview of PV, battery and hybrid inverters. **This research focuses on PV and hybrid inverters.** (Whilst battery inverters are relevant to the research, the installed base of these is much smaller and they are considered out of scope).
- We consider an inverter 'ready for **Smart Energy Services**' when they offer energy insight and/or remote control. It still may need a connection to the device to access these functionalities, but the inverter itself is ready for Smart Energy Services.

Scope

- This research focuses on **residential inverters.** Residential inverters are usually up to 6kW, but large residential inverters can be 8 – 10 kW. Commercial inverters (up to 25kW) are not considered as part of the research.
  - Whilst most residential PV systems will be installed in single family homes, it is possible for solar PV systems to be installed in apartment blocks. These are considered in scope where they feed directly into the residential homes.
  - The average size of a residential PV inverter in the Netherlands is estimated to be 4kW, the average PV system is 4.7 kW.
  - Inverters for large-scale social housing projects were out of scope.

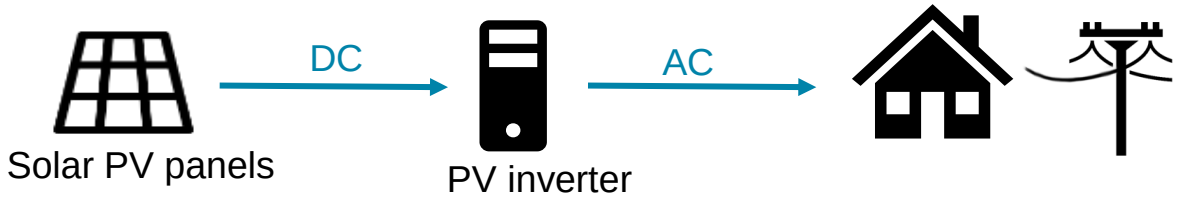
Types of inverters considered in this research

Inverter options today are PV, battery or hybrid

Where solar PV or a battery is installed as a single item, they will be installed with the associated inverter. Where PV and a battery are installed together, they will have a hybrid inverter (or could be installed with an inverter each).

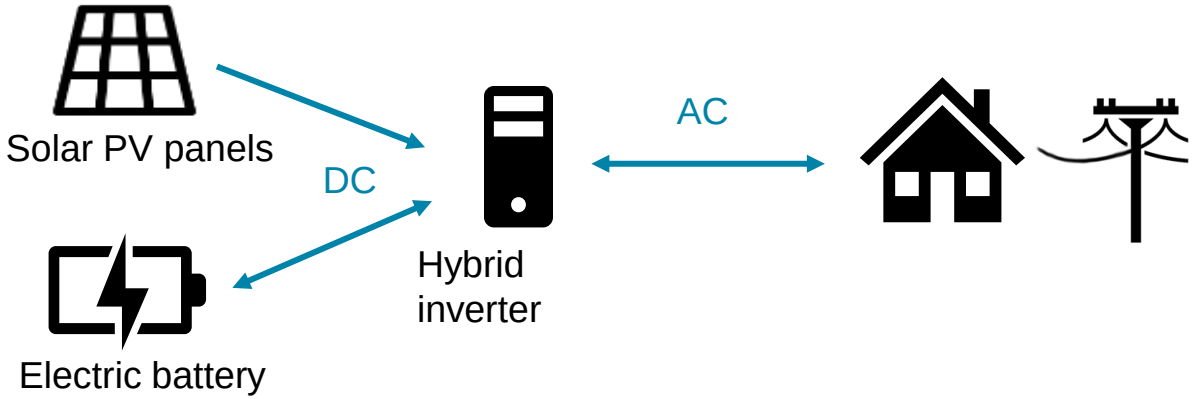
This research focuses on PV and hybrid inverters.

Solar PV inverter



One direction

Hybrid inverter



Bi-directional

PV Inverter Market in NL

> **Market overview**
> **Key manufacturers and market shares**

Market overview

The NL residential PV inverter market continues to grow

The NL residential PV market has grown rapidly over the last few years. Annual sales are expected to continue to grow, with the immature battery market growing from the late 2020s.

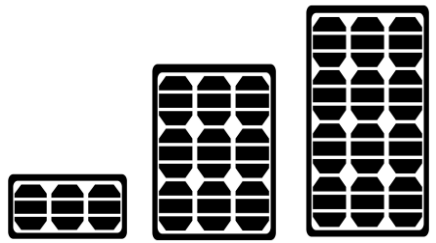
The replacement market is growing.

Most current residential PV inverter sales are linked to new PV systems. However, the replacement market for inverters that are faulty or at the end of their lifetime (approx. 10 – 15 years) will grow as systems age.

Replacement inverters could have more advanced functionality in relation to flexibility than those they replace.

Solar PV annual sales

We estimate that about 300,000 residential solar PV systems will be sold in the Netherlands in 2020*.



Annual Sales

2015 **:	2020:	2023:
~91,000 ~0.4 GW	~300,000 ~1.4 GW	~400,000 ~1.9 GW

Installed base (2019)
~0.98 million, ~ 3.9 GW

** Source: Delta-EE Connected Home Service.*
*** Source: Klimaatmonitor*

Key trends

Pre-2020

- The NL residential PV market has grown rapidly, by at least 10% each year. It is now one of the biggest in Europe, in relative and absolute numbers.
- According to the Planbureau Leefomgeving PBL (Netherlands Environmental Assessment Agency), PV capacity (including commercial) was around 4.6 GW in 2018 in the NL. Residential PV made up the majority of this capacity, although commercial PV is growing even faster than residential PV.

Future

- Net metering may gradually phase out after 2023. If so, this is expected to drive a growth in the sales of home batteries (potentially alongside existing as well as new PV systems) but not until the late 2020s when the economics stack up.
- A feed-in system is expected to be introduced in 2023 which will provide payback to homeowners in seven years.
- The growth in residential PV is expected to continue, due to Government ambition to improve the environmental sustainability of homes.
- Whilst the majority of PV inverter sales have been connected to new PV systems, sales of replacement inverters will increase. Inverter lifetime is typically 10 – 15 years (it can be longer) and therefore older systems will increasingly need replacement inverters. Householders may also wish to purchase more advanced and controllable inverters.

Key players and market shares

A competitive and crowded market with at least 12 manufacturers

The two market leaders have over half of the market share. 5 others have medium shares around 7-15% each.

European manufacturers have maintained strong market positions in the recent years.

Chinese manufacturers are increasing their market share.

The residential PV inverter market in the Netherlands is **competitive** with a large number of active manufacturers and portfolio of products.

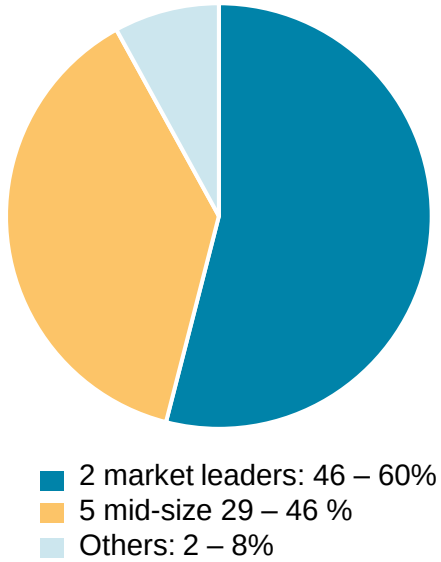
Key players:

- The top two manufacturers dominate over half of the market.
- There are a few players with medium sized market shares from 7 – 15% each, translating to 17-26,000 units in 2019 each.
- Smaller manufacturers have annual sales estimated to be less than 5,000 a year each.

Distribution: residential solar PV systems are sold to consumers by a large network of small installers. In turn they purchase systems from a small number of wholesalers.

The route to market may influence consumers' choice of inverters, for example depending on the product choice from their installers.

Residential inverter market



Note: these are estimated market shares and annual sales based on publicly available data and selected industry conversations. Many manufacturers were unable or unwilling to provide more precise figures.
It is assumed that the average residential PV inverter in NL is 4kWp.

Inverter functionality

> Types of inverter functionality and ability of inverters to participate in flexibility

> Communication protocols

> Future outlook

Inverter functionality

What do we mean by inverter functionality?

Functionality of inverters relates to the intelligent and smart functions enabling users to view PV and/or energy consumption, and control the inverter – which may be done for several reasons.

This section assesses the smart functionality and connectivity of residential PV inverters.

In our assessment, we have identified **5 levels of smart control**:

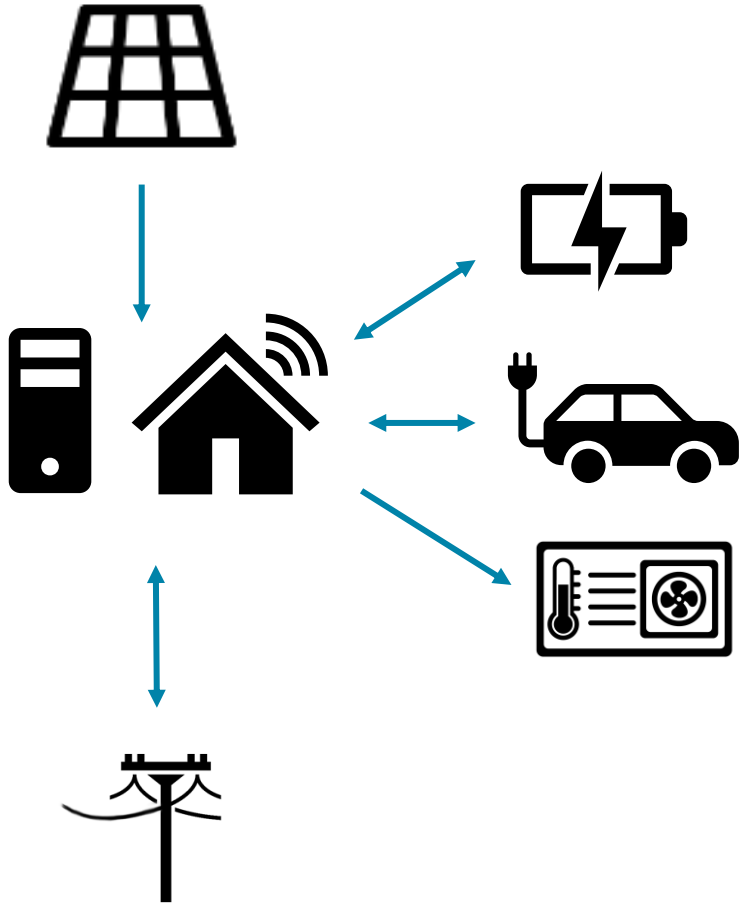
1. Dumb / blind
2. Monitoring and energy insight *(only)*
3. On/off remote control *(only)*
4. Modulating remote control (one direction)
5. Modulating remote control (bi-directional)

Delta-EE and FAN envision **three categories** for inverter functionality based on the *purpose* of this functionality:

1. Energy insights, monitoring and remote diagnostics
2. In-home optimisation
3. Flex ready

Further explanation of levels and categories is provided on pages 16 - 18.

Note: these three categories *are not mutually exclusive* i.e. inverters with energy insights functionality *may also* be flex ready.



Inverter flexibility levels

Inverters were assessed against five definitions

Limited/basic functionality

Advanced functionality

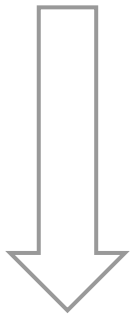
Inverter functionality	Definition	Approx. % of sales	Prevalence and explanation
1. Dumb / blind	No connectivity or 'smart' elements.	0%	None of the inverters available on the market can be classed as dumb.
2. Monitoring and Energy Insight	Monitor solar system to track performance and fault detection.	16 – 30 % of **all** inverters	All available residential inverters have this functionality; but only 20% *only* have this functionality (i.e. do not also have remote control). *This is described in more detail on page 18.*
3. On/off remote control	The inverter can be switched on and off remotely.	14 – 20 % of **all** inverters	This functionality exists to enable a PV system to shutdown in an emergency (known as 'rapid shutdown'). This is a requirement under US regulations but not in Europe. It could in theory be used for other reasons (e.g. grid services), but this seems more likely to be developed where inverters have modulating remote control (4 or 5).
4. Modulating remote control (one direction)	The inverter can be turned up or down remotely. One direction means it can only *feed into* the grid. This is the highest level of flexibility that one-directional inverts can offer.	57 – 75 % of **PV** inverters	This functionality exists in more advanced inverters, although in the Netherlands this functionality is not currently used. *This is described in more detail on page 19.*
5. Modulating remote control (bi-directional)	The inverter can be turned up or down remotely. Bi-direction means it can *feed in and consume from* the grid.	57 – 75 % of **hybrid** inverters	As above.

Inverter smart energy functionality

Three categories of ‘smart energy purposes’

Given the focus of this research was the functionality of residential inverters in relation to being ‘flex ready’, three categories of inverter functionality have been established based on the *purpose* of this smart control. These are described on the following page.

Limited/basic functionality



Advanced functionality

Energy insights, monitoring and remote diagnostics

In-home optimisation

Flex ready

Functionality available in ALL residential PV inverters on the market

Functionality available in over 50% of the residential PV inverters on the market

Note 1: Even when the inverter itself is Flex Ready, integrating Inverters into Smart Energy Service is still not very scalable. Some hurdles: There is no standard for unlocking flexibility, additional extra hardware may be needed, cloud services from manufacturers may be required

Note 2: One manufacturer stated that they have no specific views regarding warranty on its inverters and modulating feed-in or feed-out. We have not received any other mentions of manufacturers fearing extra wear on inverters when modulating the feed-in or feed-out

Inverter functionality – how can it be used?

The categories are: energy insights, in-home optimisation and flex ready

The manufacturers who are market leaders in the Netherlands are also those with the most advanced inverters.

Energy insights, monitoring and remote diagnostics

All residential PV inverters in the current sales portfolio have remote monitoring to track solar generation, system performance and detect faults. The intelligence and monitoring systems are becoming more advanced.

Most inverters currently available can also track the home's electricity consumption with the assistance of an additional meter.

Inverters will typically come with a mobile app or web portal to view the monitoring system. Increasingly, inverters do not have a display on the unit and instead connect (via Wifi) to a remote device for users to view the monitoring system.

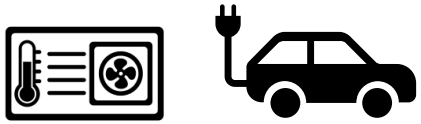
In-home optimisation

Some inverters currently available on the market can connect to energy loads in the home to maximise self-consumption of PV-generated electricity consumed within the home. This can include a battery, hot water tank, EV charger or smart appliances.

However, this functionality often requires an additional controller or meter.

Due to net metering, there has not been a strong driver in the Netherlands to maximise self-consumption in homes. However, this will increase as net metering is phased out.

In-home optimisation can be done intelligently by measuring energy flows and diverting electricity optimally. As connectivity and Home Energy Management (HEM) increases, it is anticipated that functionality will develop further.



Flex ready

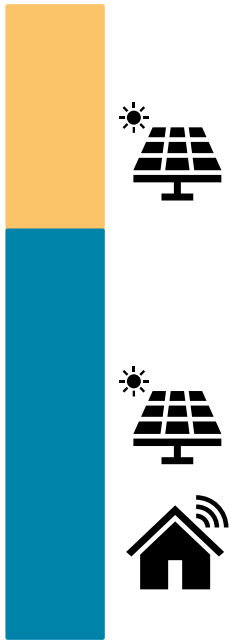
Some residential PV inverters in the current offering have modulating remote control: the amount of electricity being fed into the grid (or imported by a hybrid inverter) can be turned up or down. This will be one-way for a PV inverter and potentially bi-directional for a hybrid inverter (although not all hybrid inverters will have this functionality).

This functionality makes an inverter 'flex ready' as it could operate in grid services.

In the Netherlands, this functionality exists in certain inverters, but is not currently used. However, in other countries regulations imply that DSO's or energy suppliers must be able to remotely control inverters. In Germany, an extra 'curtailment device' is added when DSOs wants curtailment measures. Similar regulation does not exist in the Netherlands, but it may come in

How many inverters are ready for smart energy services?

By the end of 2019 around 556-732,000 residential PV inverters were ready for some sort of Smart Energy Services.



Approximately **244,000 – 420,000** residential inverters (25 - 43%) are not ready for smart energy services

This represents ~ **1.0 - 1.7 GW**

Approximately **556,000 – 732,000** (57 - 75%) residential inverters are ready for some sort of smart energy services

This represents **~ 2.2 – 2.9 GW**

Assumptions

- By the end of 2019, there were 976,000 residential PV inverters installed in the Netherlands.
- The average residential PV inverter size assumed to be 4kW.
- The total installed capacity of residential PV inverters is around 3.9 GW.

- Following from research calls with the 3 major players, it is assumed that all inverters installed by these the manufacturers are ready for remote on | off since 2005, which was a requirement for some international markets.
- Yet, even when the inverter itself is technically flex ready, integrating modern inverters into Smart Energy Services is not very scalable, let alone *older* models. See page 17. FAN therefore prefers to classify these as '**ready for some sort of smart energy services**'.

- It should be noted that most manufacturers do not currently sell 'flex ready' inverters, and that flex functionality is not used in the Netherlands at this time.

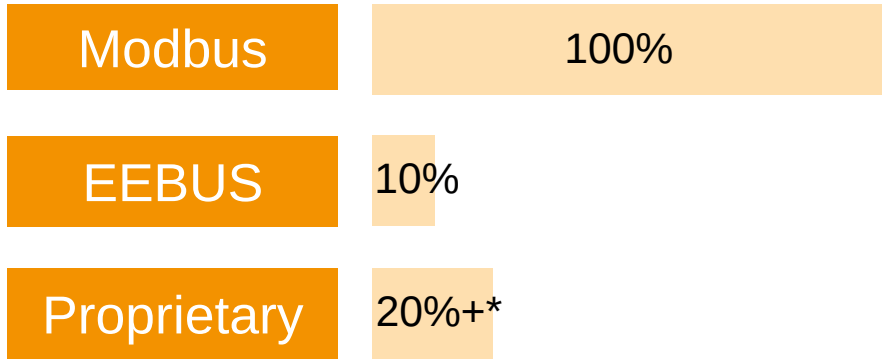
Communication protocols

Most common is Modbus but there is a move towards EEBUS

By far the most common communication protocol used by residential PV inverters is Modbus, with all manufacturers using this.

However we believe there may be a move towards EEBUS with one manufacturer now moving this. At least two manufacturers have their own protocols in addition to using Modbus and EEBUS.

Communication protocols used by ten PV inverter manufacturers:



Types of communications:
The following are all used by PV inverter manufacturers. RS485 is most common, with 9/10 manufacturers using it. Some forms of communication (such as Wifi or GPRS) are optional on inverters.

- RS485
- WLAN / Wifi
- Ethernet LAN
- Smart dongle using 2G / 3G / 4G
- 4-DI
- ZigBee
- Cellular
- GPRS

Detailed information:

- **Modbus:** As illustrated in the diagram on the left, all the manufacturers we looked at use Modbus for inverter products. Modbus RTU is used by two manufacturers, and TCP/IP by one. There is further explanation about Modbus on the next page. It is a wired protocol with RS485 used by the majority of inverter products.
- **EEBUS** is used by 1 major manufacturer. Further explanation is provided on the following page. Their inverter uses an ethernet interface and their website states that it can be used with some household appliances.
- **Proprietary protocols:** 2 manufacturers have proprietary protocols*.

Some manufacturers stated concerns about the lack of open protocols and challenges of connecting inverters with devices. However, they are seeing a slow move towards more open protocols.

** There may be more manufacturers using proprietary protocols – this information was obtained via research calls, which took place with a handful of manufacturers. Information on Modbus was obtained from manufacturer websites and verified through research calls.*

Communication protocols

Modbus is the most common protocols in residential inverters

Modbus is an open protocol, but some manufacturers use it with proprietary commands. EEBUS is an open protocol. Modbus is wired whilst EEBUS can be wireless or over ethernet.

There is a recognition from manufacturers that open protocols enable better connectivity between household energy assets and are moving towards this. However another highlighted safety concerns of being able to operate an inverter remotely.

Originally created by Modicon, **Modbus** was released as an open protocol in 2004. It enables exchanging of data.

Modbus is openly published and royalty-free, places few restrictions on vendors and is considered easy to deploy and maintain. However, some manufacturers use Modbus with **proprietary commands** to improve security.

Data transmission is however limited and not well secured.

It is a **wired** protocol.

EEBUS is a freely available, **manufacturer-independent** language, which was developed by the EEBUS Initiative, a non-profit association gathering several manufacturers, mostly European. More than 70 companies have joined the initiative and participate in the development of the protocol covering a wide range of energy-related use-cases.

Ultimately it aims to allow the **secured integration between all household energy assets** with the outside world – i.e. energy suppliers and grid operators. It is still in its early days and requires more visibility on the European market.

Data can be transmitted **wireless or over Ethernet**, between devices, to a gateway, to a cloud or between clouds.

The EEBUS offers solutions for the different communication layers (function, information, communication) which can be used independently or together.

Future market outlook

Inverters have a key role to play in growing flexibility markets

Where solar PV is installed in homes, inverters will be at the heart of a smart home and a smart grid. Their smart functionality will continue to develop.

In research calls, manufacturers addressed the importance of inverters in Home Energy Management and flexibility and pointed out that they plan to develop their functionality further.

Inverters have the potential to play a role in flexibility now but need the markets to develop.

Intelligently optimising self-generation in the home

Within the home, inverters will become increasingly important in managing and optimising energy, thereby maximizing self-generation. This will include:

- Maximising electricity used in smart appliances
- Optimising EV charging
- Shifting energy consumption
- Storing excess electricity in a hot water store or a battery

One manufacturer shared an ambition for inverters to enable “100% green consumption” in a home by optimising how solar, storage and consumption link.

With a growing PV market in the Netherlands, and the phasing out of net metering, the demand for smart inverters is likely to grow. Furthermore, the growth of smart appliances, EVs, connectivity and HEM will also give inverters a greater tole to play within the home.

Enabling the home to operate in grid services

Inverters are likely to have a growing role to play in increasingly smart grids, grid services and flexibility. They can support **grid stability** through:

- Turning up or down electricity fed into the grid
- Managing flexible loads within the home

Virtual power plants (VPPs) can also be developed using a home solar PV and battery system (and potentially EVs). VPPs can help with grid stability and meeting supply shortages.

With increasing annual sales of batteries and increasing flexibility markets, inverters are set to play an increasingly important role. This is recognised by manufacturers, policy makers and other energy system experts. We need consumers choosing *smart* inverters and we need further development of flexibility markets and services.

Disclaimer

Disclaimer

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