



BANKABILITY STUDY

Esdec FlatFix Wave Series

Esdec Solar Group

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This report presents the results of bankability study of the Esdec FlatFix Wave Series.

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Table of Contents

EXECUTIVE SUMMARY	VI
1 INTRODUCTION.....	1
1.1 Scope of Work.....	1
1.2 Methodology.....	1
1.3 Assumptions.....	1
2 PRODUCT EVALUATION	2
2.1 System Description.....	2
2.1.1 System Components	2
2.1.2 Mounting System Assembly	4
2.2 Design Parameters.....	6
2.2.1 Array Layout Rules	6
2.2.2 Design key items	6
2.3 Structural Engineering	6
2.3.1 Wind Load	7
2.3.2 Snow Load	8
2.3.3 Load Combinations	8
2.3.4 Strength	8
2.3.5 Corrosion	9
2.4 Electrical Engineering.....	9
2.4.1 Functional grounding, bonding and lightning protection	9
2.4.2 Wire Management	10
3 RELIABILITY / DURABILITY EVALUATION	11
3.1 Test Programs and Certificates	11
4 MANUFACTURING, OPERATION AND MAINTENANCE QUALITY EVALUATION.....	12
4.1 Introduction.....	12
4.2 Site Visit	13
4.3 Supply Management.....	13
4.4 Manufacturing Procedure	14
4.5 Installation	14
4.6 Maintenance and Inspection.....	14
4.7 Spare Parts	15
4.8 Warranty	15
5 BUSINESS EVALUATION.....	15
5.1 Financial Overview	17
5.2 Product Roadmap and Vision.....	19
5.3 Intellectual Property.....	20
6 CONCLUDING REMARKS.....	20
7 REFERENCES.....	21

List of figures

Figure 2-1 FlatFix Wave system.....	2
Figure 2-2 FlatFix Wave system – Components. Source: System datasheet	3
Figure 2-3 FlatFix Wave system – FlatFix Wave exploded view. Source: System assembly manual	5
Figure 2-4 FlatFix Wave array/segment in the scale wind tunnel by Peutz (left) and uplift test by Esdec (right).....	7
Figure 2-5 FlatFix Wave MLT bending test	9
Figure 2-6 FlatFix Wave Teeth surfaces	10
Figure 4-1 the access and safety marks on site	13
Figure 4-2 FlatFix Wave walkway spacing	15
Figure 5-1 Esdec Business Units	16
Figure 5-2 Esdec history and growth over the years.....	17
Figure 5-3 Research & Development Vision	19

List of tables

Table 2-1 FlatFix Wave design guidelines	6
Table 3-1 FlatFix Wave Product Test Certificates.....	11
Table : Summary of key financial figures(x1000 EUR).....	18

List of abbreviations

Abbrevia- tion	Meaning
AHJ	Authority Having Jurisdiction
DNV	Det Norske Veritas
EBITDA	Earnings before interest, taxes, depreciation, and amortization
EN	European Standard (e.g. Eurocode)
ETN	<i>Enquête de Technique Nouvelle</i>
GCR	Ground Coverage Ratio
GM	Ground-mount
H	Building Height
IBC	International Building Code
IE	Independent Engineer
L	Left
MA	Mechanical Attachment
MC4	Multi-Contact, 4 millimetre (connector/cable)
MLT	Mechanical Load Test
PV	PhotoVoltaics
R	Right
VDE	<i>Verband der Elektrotechnik, Elektronik und Informationstechnik</i>
ZM	Zinc-Aluminum-Magnesium

EXECUTIVE SUMMARY

DNV has been engaged by Esdec Solar Group (Customer/Esdec) to undertake an independent technology assessment of a solar rooftop mounting system called Esdec FlatFix Wave. The aim of the assessment is to provide an independent opinion on the system that can be used by Esdec to increase the reliability in stakeholders decisions.

DNV started the review in April 2022 and finished in August 2022.

Business Evaluation

Esdec is founded in 2004 and is now part of the Esdec Solar Group. The Esdec Solar Group was founded in 2018 and consists of 7 business-units operating worldwide. These business units share R&D knowhow, market regulations and particularities, test facilities / knowhow and support services. Turnover is nowadays up to half a billion euros and the Group has over 400 employees. Further information is given in chapter 5.

Product Evaluation

DNV has assessed the following information as part of the system overview;

- Design documentation including experimental tests
- Design documentation of the Esdec design software
- Production installation and maintenance manuals

Esdec's FlatFix Wave system is a fixed-tilt, rooftop PV racking system consisting of steel structural members, wind deflectors, and specially-designed mounting connectors to support the PV modules. Esdec rooftop systems are ballasted systems designed for both commercial and industrial flat roofs. The FlatFix Wave system is arranged as a dual tilt system with -10° and 10° tilt angles, with modules facing east and west.

DNV has conducted a review and conformity analysis of the relevant system assembly, electrical and structural aspects, wind tunnel reports, certificates, component and system strength testing, and component and project layout. Esdec's understanding and investment in the wind tunnel testing program are industry-leading. Esdec's standard structural calculations package, combining wind tunnel and mechanical lift test data supplemented with (national) Eurocode regulations, is acceptable for Authorities Having Jurisdiction (AHJ) such as France, Netherlands, Germany and, generally, EU countries. Finally, Esdec's structural testing program is extensive and DNV looks very favorably on the rigor, quality, and documentation of performed tests.

Reliability Evaluation

DNV reviewed all available tests and certificates regarding the structural integrity and the resistance against environmental conditions and accidents. The tests cover comprehensive topics including fire resistance, corrosion, earthing, lightning and wind tunnel load measurement. DNV observed that all tests of the functionality of the system have been performed according international standards

Manufacturing Quality Evaluation

Esdec acquired ISO 9001-2015 (May, 2022), the certified for its Quality Management System that aims creating the highest possible customer satisfaction certificate, with no non-conformity issue. The outcome of the ISO audit showed that the sales and marketing processes have high quality and clear strategy. Currently, Esdec focuses on plans to improve the logistics and delivery of the product. DNV visited Esdec headquarter and main storage and logistic space, administration and design



offices and the mechanical and electrical workshops. Based on the observations and certificates, DNV expects the same quality for the manufacturing processes considering Esdec is regularly audited for Factory Production Control, however, DNV has not visited the manufacturing facilities.

Operations and Maintenance

Esdec provided documentation and recommendation regarding the installation, operation and the maintenance of the product. Customer also have detailed sales terms and conditions and warranty agreement. DNV assessed the installation manual as part of the product evaluation. Additionally, DNV has observed that Esdec holds inspection and maintenance forms and they use international recommended practices as the base for their inspection and maintenance recommendations.

Concluding Remarks

In its role as independent engineer, in addition to information gathered from Esdec representative, DNV has studied documentation provided by Esdec regarding the technical aspects of the FlatFix Wave mounting system, along with manufacturing and business systems. Based on available information, testing and engineering that is indicated to have gone into the FlatFix Wave rooftop mounting products, DNV considers Esdec to be an organization which is well funded with strong financial health that, through qualitative design processes and extensive test procedures, is capable to supply suitable mounting systems that do not pose any atypical risks.



1 INTRODUCTION

Esdec Solar B.V. (Esdec) requested DNV Netherlands B.V. (DNV) to conduct a Bankability Study of the FlatFix Wave Series of solar flat roof mounting system.

The study focuses on the FlatFix Wave (10° tilt) mounting system. The FlatFix Wave mounting system is a ballasted system designed for commercial and industrial roof applications.

1.1 Scope of Work

The primary objective of this report is to assess factors that would affect the final product's performance and reliability in the field and the Company's ability to deliver and service the products. Such factors include the product design, quality of materials, product performance, regulatory compliance, reliability tests, and the manufacturing and quality control processes.

DNV has divided the bankability study into several main topics for evaluation as following :

- Product Evaluation
- Reliability/Durability Evaluation
- Manufacturing and Quality Evaluation
- Operation and Maintenance Evaluation
- Business Evaluation

To perform the assessment, DNV relied on documentation provided by Esdec and conversations with key staff associated with the topic areas covered.

1.2 Methodology

Studies of this type are often conducted to provide potential investors and financial institutions with an increased level of confidence that the product can perform according to the manufacturer's stated claims and industry expectations. This report will be directed to an audience of Esdec clients, PV project developers, and financiers. DNV is uniquely qualified to conduct this study due to its extensive background and experience in solar independent engineering and technology due diligence work.

This report is based upon information provided by Esdec to DNV via electronic media, direct meeting and phone calls. The information provided to DNV for review has included engineering drawings, test reports, installation procedures, quality plans, operations and maintenance documentation, and numerous related documents. DNV has not visited Esdec's manufacturing facilities but reviewed documentation to understand and evaluate the manufacturing approach.

Esdec has been open and forthcoming in providing the data requested. The primary Esdec contributor of information for this report was Arno Damhuis, Manager Compliance & Testing at Esdec Solar Group.

1.3 Assumptions

This report summarizes DNV's assessment of the technology and relies on the accuracy of the information provided by Esdec. Esdec has been open and forthcoming in providing the data that DNV has requested.

This report is based on some information not within the control of DNV. DNV believes that the information provided by others is true and correct and reasonable for the purposes of this report. DNV has not been requested to make an independent analysis or verification of the validity of such information. DNV does not guarantee the accuracy of the data, information, or opinions provided by others.

In preparing this report and the opinions presented herein, DNV has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. DNV believes that these assumptions are reasonable for the purposes of this report, but actual events or conditions may cause results to differ materially from forward-looking statements.

2 PRODUCT EVALUATION

The technology evaluation focuses on the FlatFix Wave (10° tilt) mounting system structural and electrical conformities.

2.1 System Description

The FlatFix Wave mounting system is a ballasted system designed for commercial and industrial roof applications. The FlatFix Wave system concept and its appearance on a rooftop are shown in Figure 2-1.



Figure 2-1 FlatFix Wave system

2.1.1 System Components

The FlatFix Wave system is composed of six major components: FlatFix Wave Dual Unit, FlatFix Wave Connection pin, FlatFix Wave Cable and Ballast brackets, FlatFix Wave Wind deflector Set L&R, FlatFix Wave Stabilizer and FlatFix Wave Base plate (Figure 2-2). See an exploded view in Figure 2-3.

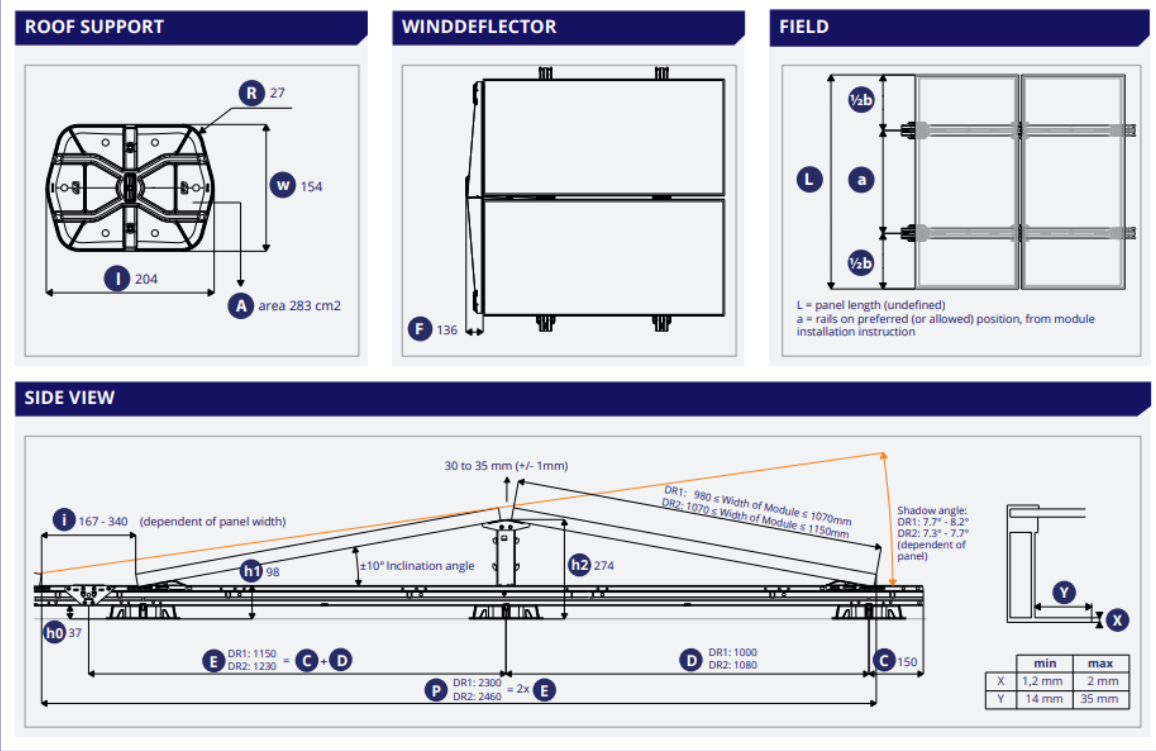
All structural components are S250GD steel class and Magnelis coated. The exceptions are FlatFix Wave brackets and FlatFix Wave Connector pin made of steel Beznal-protected and FlatFix Wave Base plate of Mafill (high-quality polypropylene). All deemed as suitable for their structural purpose according to DNV's viewpoint.

FlatFix Wave Dual Unit is a highly engineered component that gets shipped to the project site with preinstalled roof supports called Base plate.. FlatFix Wave Dual Unit is the key element of the system.

FlatFix Wave Dual Unit comes in three configurations: FlatFix Wave Dual Start Unit, FlatFix Wave Dual Unit and FlatFix Wave Dual Unit 2P, and they accommodate two different module widths: 990 mm to 1,070 mm (DR1) and 1,070 mm to 1,150 mm (DR2). With regards to module dimensions, FlatFix Wave is suitable for: i) Up to 2,400x1,150 mm; and ii) from 2,400 up to 2,500x1,150 mm with extra measurements for edge zones. It praises the versatility of the system.

Below, FlatFix Wave Dual Unit is shown together with the rest of structural components.

SYSTEM DIMENSIONS OVERVIEW (mm)







<p>Item.no. 1009100</p> <p>FlatFix Wave Plus DR1 Max. panel width: 990 - 1070mm</p> <p>Max. panel length: 2250mm</p>  <p>Material: Steel Magnelis coated PP Weight: 8,9 Intrastat: 73089098 Barcode: 8719925884627</p>	<p>Item.no. 1009101</p> <p>FlatFix Wave Dual Unit 4P Max. panel width: 990 - 1070mm (DR1)</p>  <p>Material: Steel Magnelis coated PP Weight: 8,9 Intrastat: 73089098 Barcode: 8719925884634</p>	<p>Item.no. 1009102</p> <p>FlatFix Wave Dual unit 2P Max. panel width: 990 - 1070mm (DR1)</p>  <p>Material: Steel Magnelis coated PP Weight: 4,45 Intrastat: 73089098 Barcode: 8719925884641</p>	<p>Item.no. 1009123</p> <p>FlatFix Wave Ballast bracket</p>  <p>Material: Steel Weight: 0,13 Intrastat: 73262000 Barcode: 8719925884580</p>	
<p>Item.no. 1009150</p> <p>FlatFix Wave Plus DR2 Max. panel width: 1070 - 1149mm</p> <p>Max. panel length: 2400mm</p>  <p>Material: Steel Magnelis coated PP Weight: 9,173 Intrastat: 73089098 Barcode: 8719925885365</p>	<p>Item.no. 1009151</p> <p>FlatFix Wave Dual Start unit 4P Max. panel width: 1070 - 1149mm (DR2)</p>  <p>Material: Steel Magnelis coated PP Weight: 9,05 Intrastat: 73089098 Barcode: 8719925885372</p>	<p>Item.no. 1009152</p> <p>FlatFix Wave Dual Unit 2P Max. panel width: 1070 - 1149mm (DR2)</p>  <p>Material: Steel Magnelis coated pp Weight: 4,59 Intrastat: 73089098 Barcode: 8719925885389</p>	<p>Item.no. 1009124</p> <p>FlatFix Wave Cable bracket</p>  <p>Material: Steel Weight: 0,027 Intrastat: 73089098 Barcode: 8719925884665</p>	
<p>Item.no. 1009110</p> <p>FlatFix Wave Stabilizer 2900</p>  <p>Material: Steel Magnelis coated Weight: 3,57 Intrastat: 73262000 Barcode: 8719925884535</p>	<p>Item.no. 1009111</p> <p>FlatFix Wave Stabilizer 3530</p>  <p>Material: Steel Magnelis coated Weight: 4,35 Intrastat: 73262000 Barcode: 8719925884542</p>	<p>Item.no. 1009103</p> <p>FlatFix Wave Wind deflector kit</p>  <p>Material: Steel Magnelis coated PP Weight: 3,062 Intrastat: 73089098 Barcode: 8719925884658</p>	<p>Item.no. 1009120</p> <p>FlatFix Wave Base plate</p>  <p>Material: PP Weight: 0,114 Intrastat: 39269097 Barcode: 8719925884511</p>	<p>Item.no. 1009122</p> <p>FlatFix Wave Connector pin</p>  <p>Material: Steel Weight: 0,245 Intrastat: 73262000 Barcode: 8719925884573</p>

Figure 2-2 FlatFix Wave system – Components. Source: System datasheet

2.1.2 Mounting System Assembly

FlatFix Wave system is shipped to the site and arrives with several accessories preassembled, but the part of the mechanical assembly is completed on the roof, based on the layout drawing and installation manual provided by Esdec.

FlatFix Wave system is a unique toolless solution to install, easy to understand and unfold. All these properties allow for a significant labor time saving and make the system cost effective. The uniqueness of its mechanism makes it significantly unconventional in comparison with other systems but DNV does not expect assembly or operating issues. Specially, since this mechanism plays an important role during installation and can be controlled during manufacturing quality control (see section 4).

Below, main assembly phases are summarized by two pictures. Firstly, the unfolding process of the FlatFix Wave Dual Unit is shown. It comprises the unfolding of the High bases as well.

Secondly, the rest of the components are added to the system in an easy manner. They are fixed by predefined clamps, lips and perforations to FlatFix Wave Dual Units, High bases and Stabilizers.

In particular, DNV highlights that MC4 connections and cables as well as ballast pieces are proposed to be installed in a controlled and predefined manner.

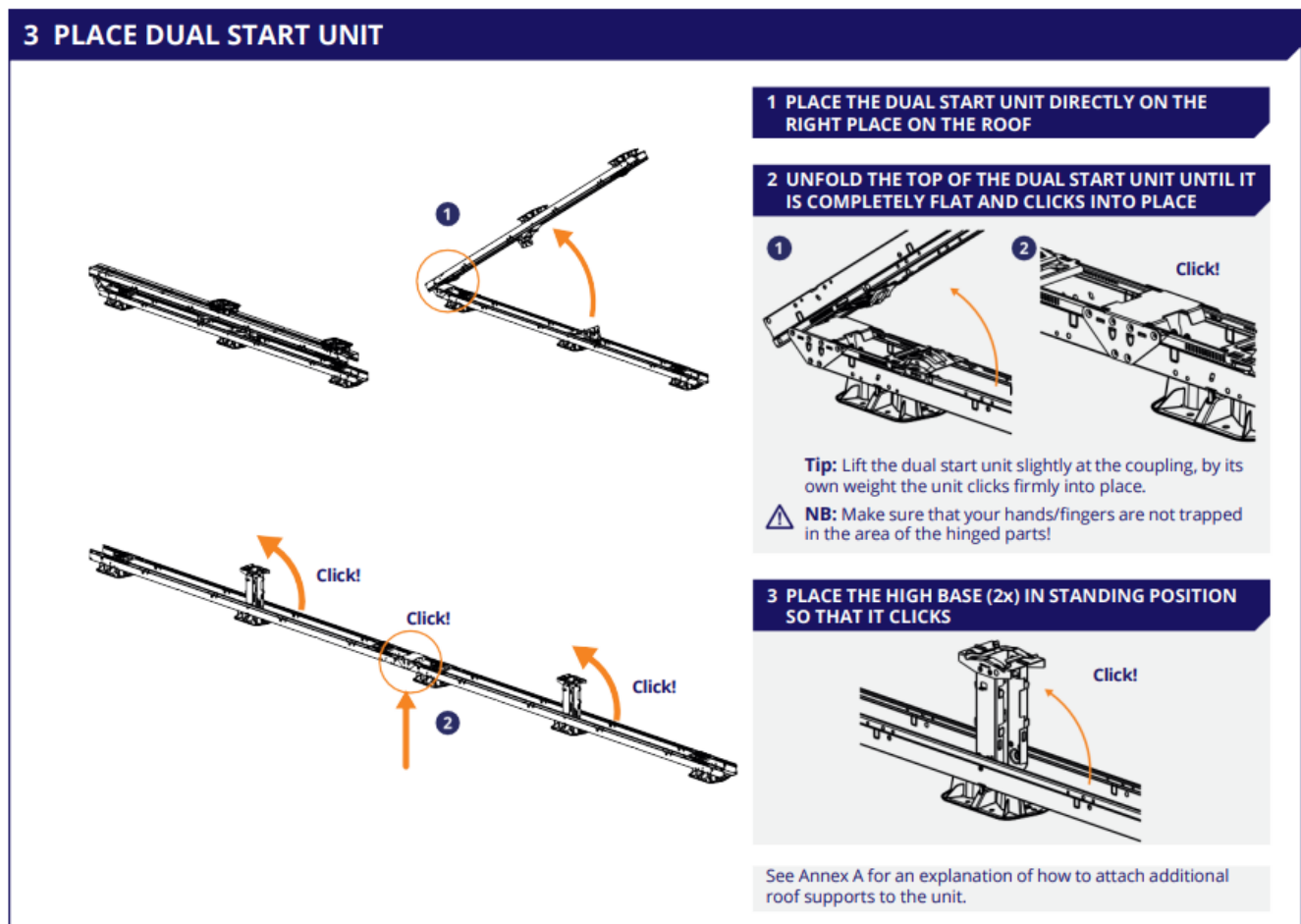
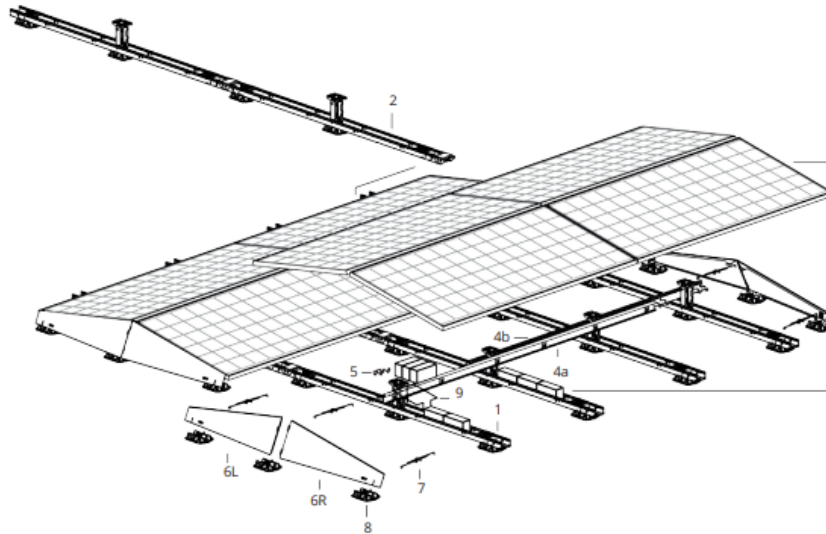
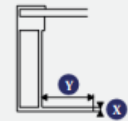


Figure 2- 3 FlatFix Wave system – FlatFix Wave Dual Unit unfolding. Source: System assembly manual

1 BILL OF MATERIALS

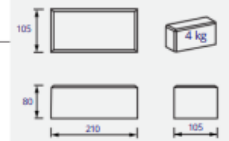


PANEL FRAME



	min	max
X	1,2 mm	2 mm
Y	14 mm	35 mm

BALLAST



UNITS



- 1a. FlatFix Wave Dual Start unit 4P DR1
1009101
- 1b. FlatFix Wave Dual Start unit 4P DR2
1009151



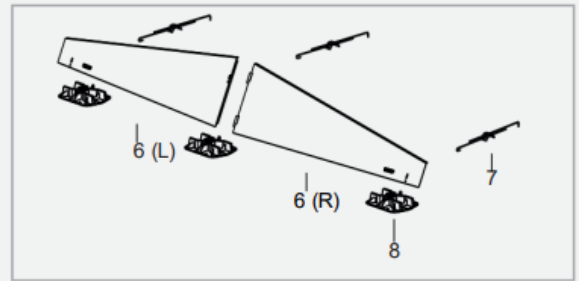
- 2a. FlatFix Wave Dual Unit 4P DR1
1009100
- 2b. FlatFix Wave Dual Unit 4P DR2
1009150



- 3a. FlatFix Wave Dual Unit 2P DR1
1009102
- 3b. FlatFix Wave Dual Unit 2P DR2
1009152

DR1 (Dual range 1): panel widths 990mm to 1070mm
DR2 (Dual range 2): panel widths 1070mm to 1150mm

WIND DEFLECTORS



6. FlatFix Wave Winddeflector
DR1 kit (= wind deflector L and R)
1009103

7. FlatFix Wave Connector pin (set of 3)
1009122

8. FlatFix Wave Roof support
1009120

STABILIZERS

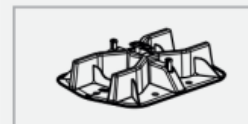


- 4a. FlatFix Wave Stabilizer 2900
1009110
- 4b. FlatFix Wave Stabilizer 3530
1009111
- 4c. FlatFix Wave Stabilizer 4000
1009114
- 4d. FlatFix Wave Stabilizer 4350
1009115



5. FlatFix Wave Cable bracket
1009124

ACCESSORIES



8. FlatFix Wave Roof support
1009120



9. FlatFix Wave Ballast bracket
1009123

Figure 2-3 FlatFix Wave system – FlatFix Wave exploded view. Source: System assembly manual

2.2 Design Parameters

The project engineering process is provided by Esdec. For that purpose, Esdec has set up an online calculator (<https://eu.Esdec.com/en/calculator/#>) that is an easy step for any interested person or party. It evaluates all design loads based on the provided site criteria and then apply a comprehensive design guidelines ruleset before generating a Project Plan for use in permitting, budgeting, and system construction. In case of insufficient input or critical or complex design situations, Esdec’s project engineers will be consulted for calculations, advice, etc.

2.2.1 Array Layout Rules

Typical flat-roof arrays sizes are governed by roof conditions, electrical requirements and thermal effects. Esdec restricts array sizes to 40 m x 40 m (for flat roofs) and distance to edge of the roof to around 1/5 times the building height to avoid the very turbulent winds at this area.

DNV highlights that Esdec complies with the IBC fire code. According to it, array sizes cannot exceed 45 m x 45 m (see below “Fire listing” in chapter 3.1.

2.2.2 Design key items

DNV has summarized key technical information pertinent to the FlatFix Wave design guidelines in Table 2-1.

Table 2-1 FlatFix Wave design guidelines

Parameter	Description	Meets IE expectations?
Roof Loading	≈14 kg/m ² to ≈22 kg/m ² including racking, modules, and ballast.	Yes, see note 1)
Roof Slope	5° max slope (1/12 pitch) in all directions.	Yes, see note 2)
Wavy Roofs	One segment is not designed to go over roof crickets.	Yes
Wind Speed	Wind speeds require Esdec engineering review.	Yes, see Section 2.3.1
Exposures	According to Eurocode – National Annexes	Yes
Maximum Building Height	Maximum Building Height requires Esdec engineering review. Specially, if exceeding 12.0 m high.	Yes

Notes:

- 1) FlatFix Wave roof loading range allows system owners to deploy solar PV systems on roofs with low additional roof capacity available.
- 2) According to Peutz’s letter, the wind tunnel data are valid for roof tilt angles between -5° and +5°. Values outside these bounds will require to contact Esdec.

2.3 Structural Engineering

As with any PV mounting systems, main physical loads applied to the Esdec’s FlatFix Wave structure originate from wind loads, dead loads (racking system and ballast self-weights and PV modules) and snow loads. Standard requirements for the applied loads are considered according to *Eurocode EN 1991* for European countries.

The primary structural requirement for the racking structure is to support the PV modules without significant deformation or strength failures under the aforementioned design forces for the design life of the generating facility.

2.3.1 Wind Load

Generally, Esdec informs that maximum wind speed resisted by FlatFix Wave system is Beaufort Scale 11 (103 km/h to 116 km/h). If any of the prescribed wind limits is exceeded by a project, the customer is automatically lead to Esdec's project engineering department where special calculations are made in close collaboration with them.

The current state-of-the-art for solar structure design typically goes beyond the minimum code requirements to include an assessment of the unique pressure coefficients for the geometry of the structure. The pressure coefficients are typically obtained from wind tunnel testing performed on a scale model of the solar structure and an experienced wind tunnel laboratory. As is best practice, Esdec has obtained pressure coefficients from wind tunnel testing performed by Peutz in July and August 2020.

Peutz has conducted a boundary layer wind tunnel testing on a scale model of the Esdec FlatFix Wave mounting system following EN1991-1-4 Section 1.5, CUR C103 *Études en soufflerie des charges de vent sur les bâtiments (de grande hauteur)* and NEN 7250:2014 *Systèmes Énergie solaire – integration dans les toitures et façades – aspects dut bâtiment* (Figure 2-4). Peutz consulted TNO (Netherlands Organisation for Applied Scientific Research) on the obtained wind loads in order to increase the reliability of the results.

Results from Esdec's mechanical lift tests conducted in summer 2020 were incorporated into the wind tunnel data and then into the calculator of Esdec. Peutz has reviewed that these results have been correctly and safely processed in Esdec's calculations. Furthermore, the overall approach and method by Esdec have been tested and officially approved by Peutz in several reference projects (February 2022).

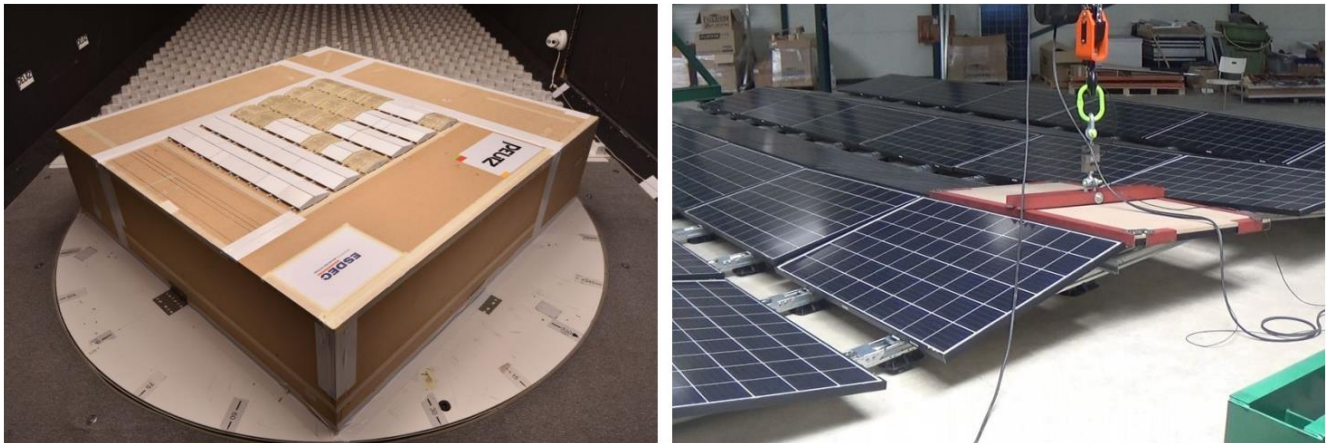


Figure 2-4 FlatFix Wave array/segment in the scale wind tunnel by Peutz (left) and uplift test by Esdec (right)

Wind tunnel results are presented in the form of pressure coefficients (C_{pe} in accordance with EN1991-1-4). They are provided based on their position on the PV segment: courant (middle of the segment), bord (NS and EW perimeters away from the corners) and angles (at the corners) as a function of the normalized tributary area. Then, two verifications are performed: on every module and a group of modules. The second one is used to secure the ballast supported by the Dual Unit that provides system stability against sliding, lifting and overturning.

2.3.2 Snow Load

Similar to wind loading analysis, site-specific snow loads need to be calculated according to local standards. Given the low profile nature of the FlatFix Wave system, the system is not able to readily shed snow and it will collect snowfall and drifting snow with no “self-shedding” ability, thus snow represents a considerable design load for design.

Esdec has shown the racking structural calculation package to include the calculation of snow design loads according to applicable European standards.

2.3.3 Load Combinations

A method for combining the effects of wind, snow and dead loads is prescribed in building codes, Eurocode for Europe in particular. Often, the design of different racking components is governed by different load cases, e.g. wind loading may control the design for a module clip, whereas snow loading may govern the design of the supporting structure. DNV has confirmed that Esdec’s load combinations are performed following European standard EN1990.

2.3.4 Strength

To be structurally adequate for the conditions at a given location, the product must demonstrate the strength capability to withstand the calculated applied loads along with an additional margin of safety to account for areas of uncertainty. In Europe, regulatory requirements for structures such as the FlatFix Wave mounting system are typically established by the following codes:

Eurocode 1: Actions on structures; and

Eurocode 3: Design of steel structures.

The typical controlling load scenario on PV racking structures is wind forces acting on the PV module glass and frames, but as noted previously all applicable loads need to be considered and combined according to appropriate standards. Each structural member in the complete load path should be analyzed for each of the load combinations. Esdec has performed it by previous physical testing which is deemed a suitable procedure according to DNV’s viewpoint (see chapter 2.3.4.1).

2.3.4.1 Mechanical Load Tests

Mechanical load testst (MLT) of the mounting system are performed to assess the allowable pressures or loads in the vertical direction, both positive (vertical down, simulating snow or wind downward loads), and negative (vertical up, simulating wind uplift). Tests were performed on the primary structure, on a two-module element using a FlatFix Wave full system and on single components (FlatFix Wave Dual Units). These mechanical tests also contribute to module clamp connections verifications (to High Base and Zipper).

Among others, the scope of the tests is the determination of characteristic values for the load-bearing of the components in order to apply for *allgemeine bauaufsichtliche Zulassung* (a “General Building Permit” in Germany).



Figure 2-5 FlatFix Wave MLT bending test

Esdec has also checked the friction coefficient to be used in the stability verification or ballast system design by subjecting the FlatFix Wave system to lifting and drag forces.

2.3.5 Corrosion

According to Esdec documentation, FlatFix Wave main structural components are S250GD structural steel coated with Z310 (Magnelis coating). Z310 is comprised of Zinc, 3.5% Aluminum, and 3% Magnesium. FlatFix Wave brackets also have superior corrosion resistance, brackets are coated with Benzinal 2000 material.

To validate the corrosion resistance of FlatFix Wave components and brackets, VDE, entrusted by Esdec, has performed Sulphur dioxide test with general condensation of moisture in accordance with ISO 6988:1997-03 and Salt spray testing in accordance with EN 60068-2-52:2018-08. From the documents reviewed, FlatFix Wave parts are performing well and passed the certification process.

2.4 Electrical Engineering

2.4.1 Functional grounding, bonding and lightning protection

An important aspect of a mounting system is the equipment grounding system. National electrical codes usually require that accessible conductive components that are likely to become energized be adequately bonded to the ground.

Furthermore, standard HD-IEC 60364-7-712 requires that, where equipotential/ground bonding is necessary, the metallic structure supporting the PV modules including the metallic cable management systems shall be bonded. This bonding conductor shall be connected to any suitable earthing terminal and have a minimum cross section of 4 mm². In addition, when metal structures are of aluminium, suitable connection devices shall be used to ensure a proper equipotential bonding.

In the case at hand, compliance with this requirement is easily fulfilled by ZM coated steel components clamped together as a robust structural assembly and electrically connected (i.e., a ground wire does not need to be run to each individual corrosion protected steel component). Nonetheless, PV frames are typically anodized aluminum and therefore have a non-conductive outer surface that must be penetrated to make a connection to a conductive material. Esdec's design addresses IEC requirements above through teeth surfaces without the need of additional means and components. Earth continuity

and integral bonding have been actually physically tested and certified by VDE in accordance with IEC 60364. Finally, a grounding connector ($\geq 4 \text{ mm}^2$ diameter) per PV field connects to at least one ground rail in an inverter (earthing terminal).

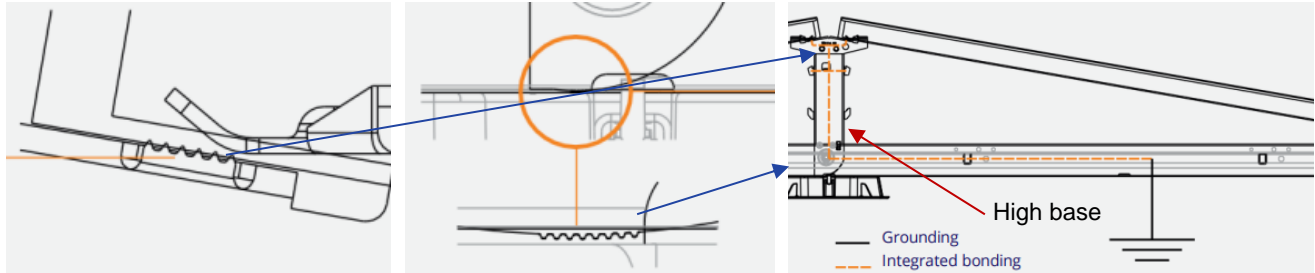


Figure 2-6 FlatFix Wave Teeth surfaces

With regards to lightning protection, FlatFix Wave system is tested, classified and approved according to EN 62305-1 Lightning Protection.

2.4.2 Wire Management

Wire management is a very important aspect of solar PV systems and involves properly routing, supporting, and protecting PV system wires and cables. Wire management components typically do not have a standard warranty, and if not properly designed, it is likely to fail first, causing safety and reliability concerns. To ensure the longevity of solar PV systems, cables need to be properly secured and protected from direct sunlight, and other weather elements. In addition, they need to be protected from metal sharp edges, rodents, and other animals. It is particularly addressed by HD-IEC 60364 standards and fulfilled by Esdec by deploying the trays below the PV modules, over the ground and tied to predefined perforations and lips.

Esdec recommends using several components such as trays for securing wiring along modules and mounting system components. It is something deemed positive by DNV as being generally missing in the market.

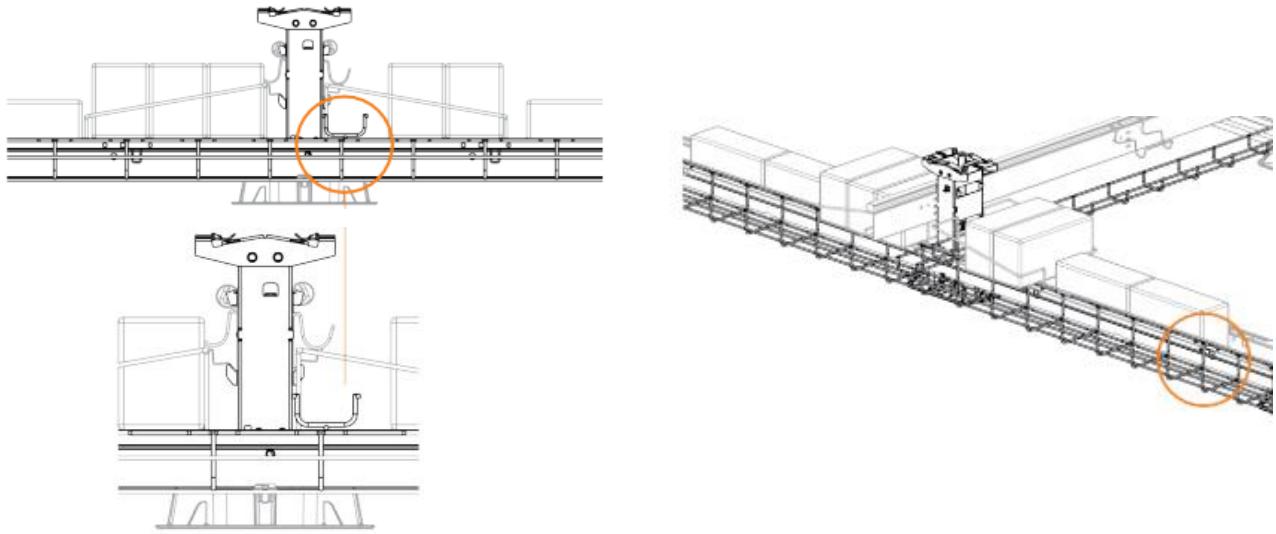


Figure 2-7 FlatFix Wave wire trays

3 RELIABILITY / DURABILITY EVALUATION

While reliability is best evaluated from lifetime and field experience, analysis and laboratory testing can also inform the perspective on expected reliability.

Esdec has supplied rooftop solar mounting structures since 2004 for over 7 GW PV power capacity. The FlatFix Wave product has been installed in the field since 2020 with over 321 MW installed capacity. The design of this system provides a toolless installation procedure which increases the efficiency and reduces the labor cost. FlatFix Wave has not received any claims over 18 projects in 6 countries.

DNV notes that project owners, developers, and sponsors have increased project useful life expectations to 35 or even 40 years of life as of lately. DNV observed a continuous effort from Esdec to follow the market and adapt the product in case of a new practice.

3.1 Test Programs and Certificates

Esdec acquires several certificates for the FlatFix Wave to assure the integrity and reliability of the product. The certificates cover both general usability and detailed technical capabilities. Table 3-1 shows the test program for the FlatFix Wave product.

Besides these tests, Esdec planned several tests which are ongoing and provide higher reliability to the system.

Table 3-1 FlatFix Wave Product Test Certificates

Parameter	Description
Earthing and Lightning Protection	General requirement from HD-IEC 60364 series with focus on protective earthing, functional bonding and lightning protection.
Corrosion of the Earthing	Assessment of effective earth continuity under corrosion.

Plasticizer Migration	Determination of the effect of plastic solar feet on PVC roof sheeting.
Rooftop Fire Performance (Fire Listing)	These installations must meet a fire resistance index called BROOF (t3) which means that the time for the fire to penetrate through the roof and for the fire to spread to an exterior roof must be greater than 30 minutes.
Reaction to Fire Performance	Testing construction material to classify their reaction to fire based on EN 13501-1 standard.
Wind tunnel testing	Wind tunnel testing has been performed on the scaled model of the FlatFix Wave on a rooftop.
Experimental load test	Uplift and down pressure mechanical load tests were performed on the units to investigate the resistance and find out the coupling parameter.

FlatFix Wave has ENQUETE TECHNIQUE NOUVELLE (ETN) and ALLGEMEINE BAUAUFSICHTLICHE ZULASSUNG (abZ) certificates which are building authority approval of useability for the construction product.

FlatFix Wave has the fire classification class of Broof (t3) according to CEN/TS 1187:2012 and EN 13501-5:2016 that is acceptable in France and other EU countries. FlatFix was tested based on EN 60068-2-52, EN ISO 6988 and EN 61439-1 for assessment of effective earth continuity.

FlatFix Wave uses corrosion protected steel from Arcelor Mittal with Magnelis coating. Esdec has performed the corrosion tests and the product warranty period is 20 years.

4 MANUFACTURING, OPERATION AND MAINTENANCE QUALITY EVALUATION

4.1 Introduction

DNV reviewed FlatFix Wave’s operation and maintenance documentation, installation procedures, and checklists. The manufacturing facilities have not been visited and the quality of the product is assessed based on quality control and supply management of Esdec as seen through the ISO 9001 Quality Management System certification.

Unlike other components of a solar facility such as PV modules and inverters that are fully assembled and tested in a factory environment, mounting systems are not completely “manufactured” until they are assembled and commissioned at a project site. The FlatFix Wave plan involves the shipment of components to the installation site, storage and staging onsite. The final assembly will be done by the contractors of the project on site. The design of the system is by Esdec and the production is done by selected, external and exclusively working for Esdec manufacturers. The manufactured components are transported and stored in Esdec’s storage hall.

In this context, DNV views manufacturing of mounting systems to include not only fabrication of components but also the installation, assembly, and final commissioning of the racking as a system on site; only upon system completion the characteristics of product conformance are measurable, and the end-product ready for acceptance by the customer.

The scope of the manufacturing review for this report includes a review of the internal process controls that FlatFix Wave uses to qualify vendors, manages the supply chain, and controls the manufacturing functions at their facility. DNV's primary focus is on the quality management system and how FlatFix Wave assures the repeatability of its processes. DNV did not conduct an on-site evaluation of the suppliers' facilities.

DNV views the adequate management of each stage of racking production, installation, and commissioning as a priority for racking suppliers to deliver a quality final product to the end-user. Review and commentary on the production and maintenance policies of components for the racking are covered in this section.

4.2 Site Visit

DNV visited Esdec main factory in Deventer, Netherlands in May 2022. The main factory includes the storage halls, logistic preparation, design offices, administration offices, Innovation center which included showroom and training center as well as and testlabs.

The storage and logistic halls were adequately signed for safety and operation and access areas were clearly marked (Figure 4-1). On the day of visit, some of the pallets were not in their designated location, which could be organised better.

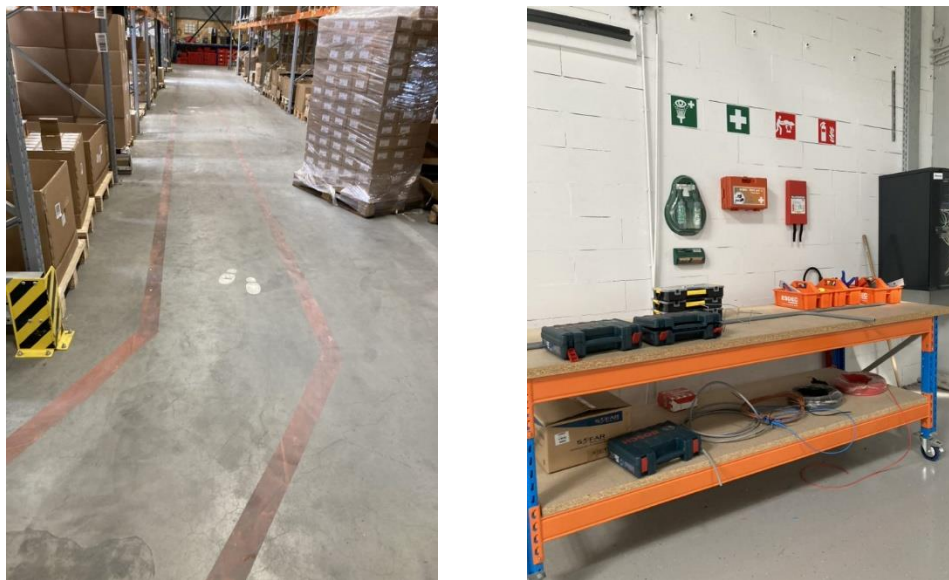


Figure 4-1 the access and safety marks on site

The storage, offices and shared areas were organized and tidy. The electrical workshop and the showrooms were organized but the mechanical workshop needed a bit more organization as tools and materials were scattered. This is expected to be solved soon as Esdec had plan to improve the tests procedures.

4.3 Supply Management

Esdec obtained ISO 9001-2015 conformity in 2022 from DNV Business Assurance. No non-conformities have been reported.

Esdec has reasonable sales and purchasing risk based strategy. In addition, they have a established system for vendor rating, suppliers audits and monitoring besides the internal auditing and PNC procedures (complaints and product deviations). The lessons learned from projects and also the data analysis on the PowerBI platform are part of Esdec's development. Although the firm has pitfalls in the logistics, there are many development actions on its list to improve the system.

DNV finds the supply management adequate at the moment with improvement actions on the list.

4.4 Manufacturing Procedure

DNV did not visit the manufacturing facilities, however, the ISO 9001 Quality Management System certificate has approved the supply chain management. In addition, as part of the ISO 9001 procedure, factory production control is done, based on which DNV expects the same level of manufacturing quality by Esdec.

4.5 Installation

Similar to most solar PV mounting systems, Esdec delivers the FlatFix Wave system to the project site and provides instruction of the racking system, installation manual and inspection checklists (Section 2 explains the installation procedure thoroughly). The installation of the mounting structure is performed by contractors and installers and Esdec does not provide any aid or supervision on installation procedure, however, technical training is provided for the technicians who are doing that for the first time on-site or off-site at the Esdec factory. This technical training provides enough knowledge to prevent probable mistakes.

The installer holds the responsibility of performing the proper checks to verify the installed system is in conformance with the installation manual.

FlatFix Wave has adequate installation manual with an illustrative procedure for the installation of the mounting system (see Chapter 2). The FlatFix Wave checklist includes delivered material, alignment and placement, and installation procedure of the components. However, it does not provide any recommendation or awareness towards visual checks of corrosion protection coating and signs of physical damage to the racking components, and proper installation and checks for damage to the modules.

As noted earlier, Esdec provides support and training of installation on-site, however, the installer is responsible for verifying the installed system is in conformance with the installation manual, racking construction set, and O&M manual.

4.6 Maintenance and Inspection

FlatFix Wave does not have a maintenance manual which explains the maintenance and inspection activities but Esdec has general maintenance and inspection checklists. FlatFix Wave maintenance and inspection checklists include:

- Initial Inspection – during construction (before system commissioning)
- Comprehensive Inspection – periodic inspection for possible maintenance
- Specific Inspection – after any severe weather event

Initial Inspection outlines very comprehensive data collection from the installation quality, system configuration, rooftop installation, and ballast conditions. Esdec recommends their customers to use international recommended practice for solar modules inspections, so they do not recommend any time period.

Comprehensive inspection includes:

- Inspect roof condition: current condition versus the as-built documentation
- Inspect for damaged and/or displaced components
- Inspect the earthing/bonding condition.

DNV recommends Esdec to create a maintenance manual and include all recommendation for inspections.

DNV also notes several FlatFix Wave product features specifically designed with constructability and O&M, however, the project developer is responsible for the layout design of the rooftop systems.

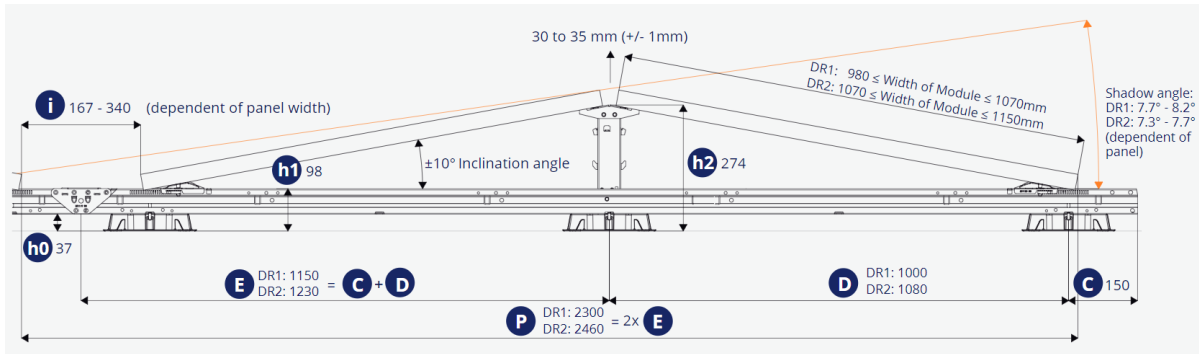


Figure 4-2 FlatFix Wave walkway spacing

DNV has not reviewed any field data to opine on the robustness of the O&M procedures. However, DNV considers FlatFix Wave's general approach to be in-line with competing racking products, and the O&M manual comprehensive and well organized. DNV views design features included for O&M as industry-leading.

4.7 Spare Parts

FlatFix Wave does not have a separate spare parts list, rather is a part of the product sheet. Any extra material or spares shipped would be a result of the sellable component quantities.

4.8 Warranty

Esdec has clear terms and conditions on sales and delivery. The terms and conditions clarify the terms upon selling the product and also specifies the intellectual property rights. Moreover, the general terms covers all necessary clauses regarding the purchase, payment, return, liability, disputed and force majeure. The product warranty warrants that the product will be free from defects in materials and workmanship for a period of 20 years from the date of shipment.

Overall the general terms and conditions and the warranty of FlatFix product appear to be standard and the longer term length than 20 years could be more favorable in the industry.

5 BUSINESS EVALUATION

Esdec founded in 2004, develops, manufactures, and supplies solar rooftop mounting solutions for the residential, commercial, and industrial markets. The company is headquartered in Deventer, The Netherlands, and has more than 7 GW of installed capacity, mostly in Europe and US. Esdec entered the US market in September 2018, acquired EcoFasten in November 2018, and acquired IronRidge and Quick Mount PV in 2019. Further in 2020, expanded their business to India, acquired PanelClaw in USA and Solar Construct in The Netherlands. The latest acquisition of in 2021 includes Solarstell in The Netherlands.

Esdec Solar Group has regional headquarters in the United States, Europe and India that manage and support the various business units.

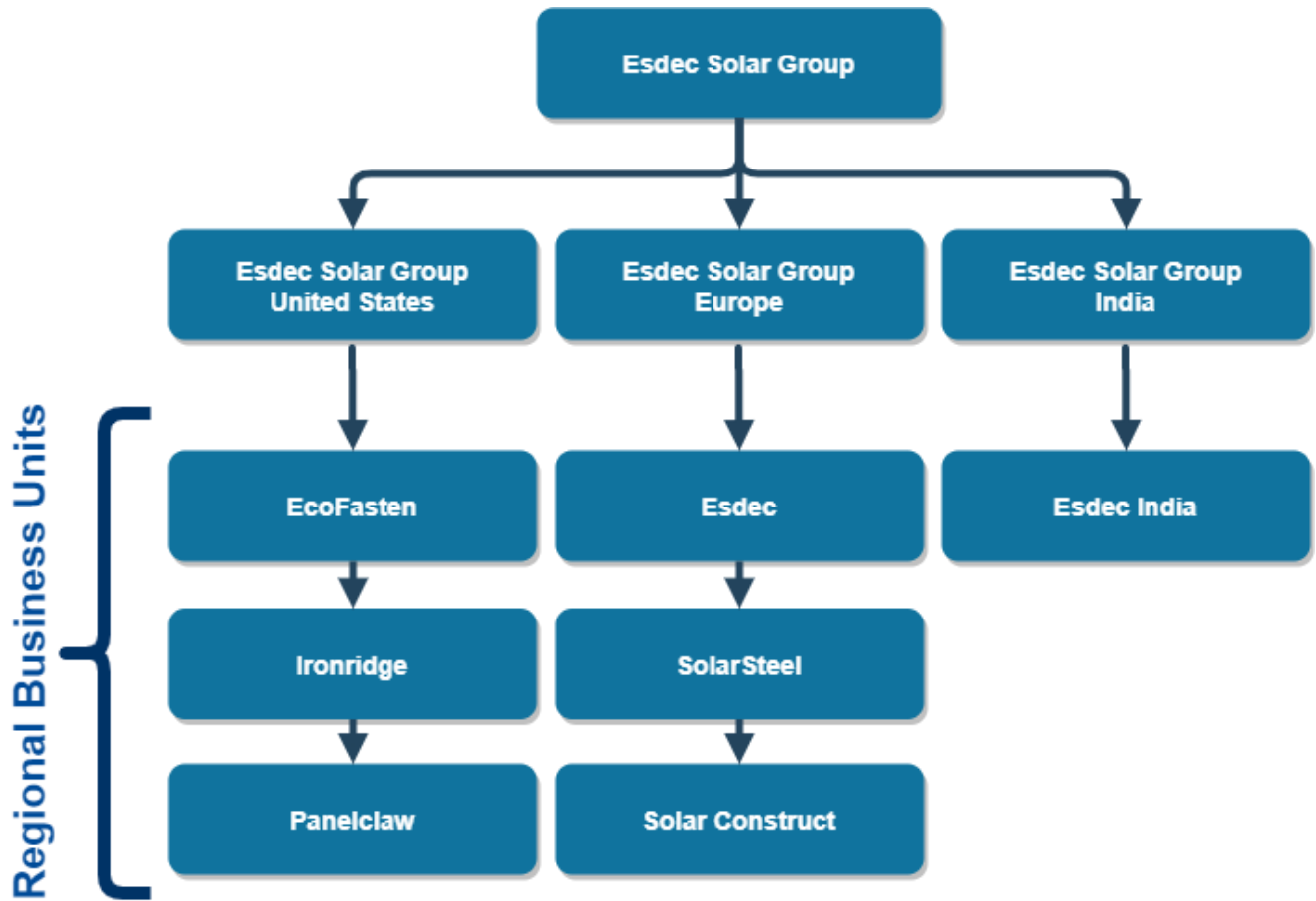


Figure 5-1 Esdec Business Units

As of 31st December 2020, a total of 266 (2019: 232) employees are working in Esdec Solar Group who represent full time equivalents. Of this, 83 (2019:59) are working in the Netherlands, 173 (2019:167) in the USA and 10 (2019:6) in the rest of Europe.

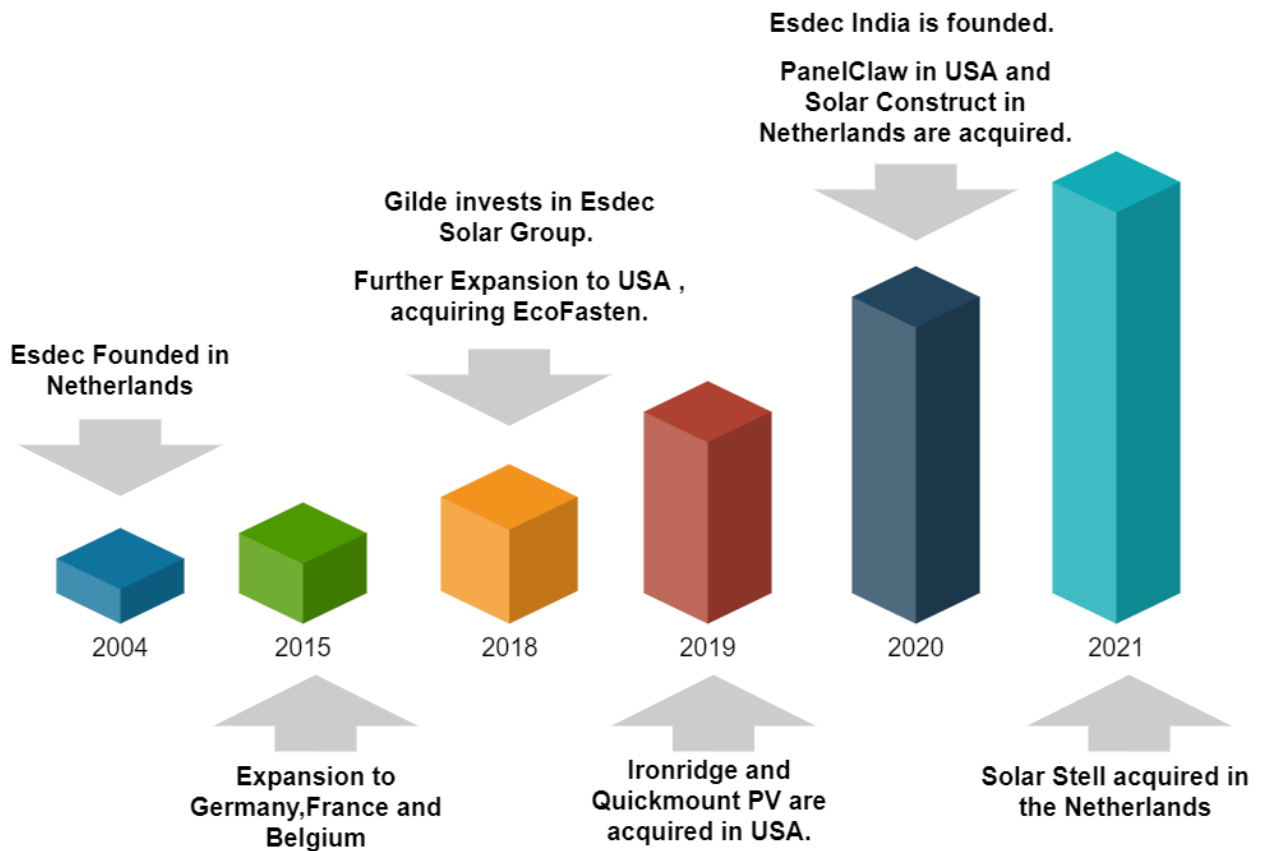


Figure 5-2 Esdec history and growth over the years

5.1 Financial Overview

The commercial overview is based on the annual report of 2020 and publicly available information, and comprise of Esdec Solar Group B.V. and subsidiaries. In 2020 Esdec Solar Group B.V. grew revenue by 60% year-on-year to a total of 244 Million EURO. The operational result was 34,4 Million EURO, improving from 11% in 2019 to 14% in 2020. The result after tax is reported as 8% in 2020, from 4% in 2019. The credit rating of Esdec Solar Group B.V. is reported as score A (Creditsafe, 11.05.2022).

Table 2: Summary of key financial figures(x1000 EUR)

Balance Sheet	31.12.2020	31.12.2019
Fixed Assets	€ 184 046	€ 181 622
Current Assets	€ 99 049	€ 87 503
Total Assets	€ 283 095	€ 269 125
Equity	€ 81 751	€ 68 066
Non-current Liabilities	€ 145 381	€ 148 758
Current Liabilities	€ 55 963	€ 52 301
Total Liabilities & Equity	€ 283 095	€ 269 125
Income Statement	31.12.2020	31.12.2019
Total Revenue	€ 243 999	€ 152 229
Total Cost	€ 209 635	€ 134 762
Operating Result	€ 34 364	€ 17 467
in percent of total revenue	14 %	11 %
Financial Income and Expenses	€ 7 557	€ 6 989
Result before Tax	€ 26 807	€ 10 478
in percent of total revenue	11 %	7 %
Income Taxes	€ 7 316	€ 3 831
Result after Tax	€ 19 491	€ 6 647
in percent of total revenue	8 %	4 %
Cashflow Statement	31.12.2020	31.12.2019
Net cash generated from operating activities	€ 49 829	€ 18 932
Net cash generated from investment activities *	-€ 33 108	-€ 87 635

Net cash generated from financing activities	-€ 12 283	€ 77 612
Net cash flows	€ 4 438	€ 8 909

*incl acquired cash from acquisitions

5.2 Product Roadmap and Vision

DNV was provided with the Research & Development plan for 2022 with a specific focus on the European market. The main vision for Research & Development is built around the core value of “increasing passion”.

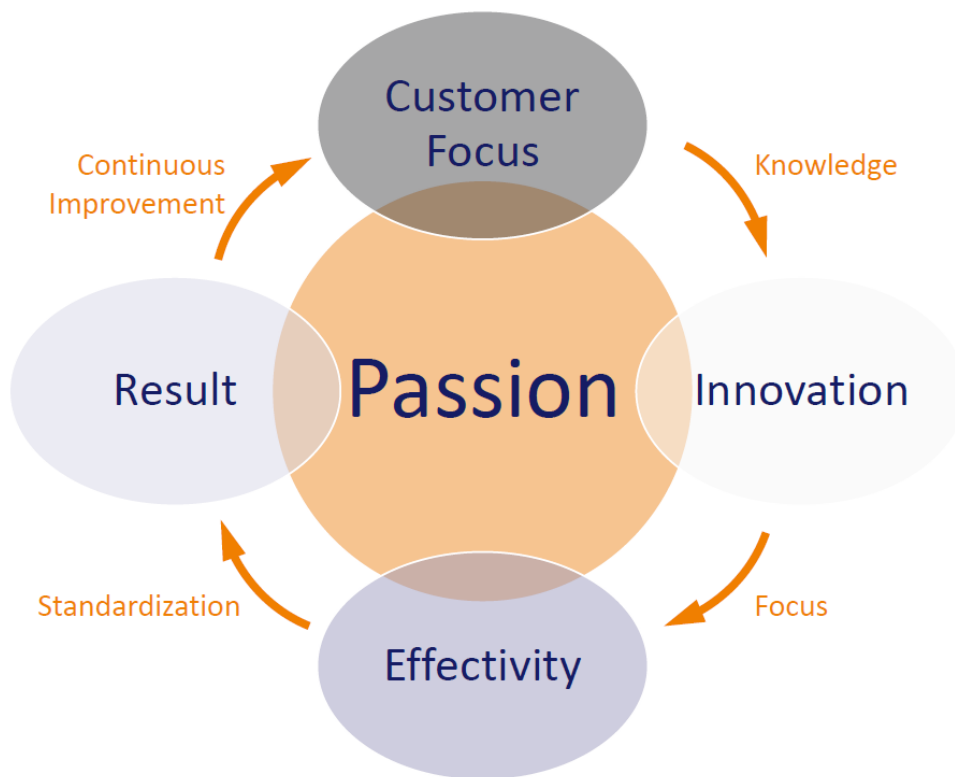


Figure 5-3 Research & Development Vision

As diagrammatically represented above, Esdec believes in focussing on the customer through gaining knowledge from the direct customers, markets and system. Further this knowledge is used to innovate and enhance focus by reducing time to market and prioritization, which helps in improved effectivity. Eventually, the organization team works towards standardization of the service/product to reach the final end result. This is eventually improved continuously by personal development, process and quality control . Esdec has a clear roadmap for new product development supported by their concrete sales strategy.

The Research & Development organization within Esdec consists of 5 departments which include Innovation, development of pitched roof, development of flat roof , research and structural Engineering and test and certification.



The entire team consists of 15-20 members as of June 2022, spread across the various departments with a strong ambition to increase the FTE further in 2022.

5.3 Intellectual Property

The comprehensive work of the research and innovation department within Esdec gave rise to many novel products with a field of patents.

Esdec currently has 17 patents globally and have a few patents pending the final grant as of May 2021. The rights of these patents are protected by the European Union and US Patent Body. The patents have been granted to Esdec for innovation in the following :

- Assembly Process
- Mounting structure
- Support structure stability
- Clamping

6 CONCLUDING REMARKS

In its role as independent engineer, in addition to information gathered from Esdec representative, DNV has studied documentation provided by Esdec regarding the technical aspects of the FlatFix Wave mounting system, along with manufacturing and business systems. Based on available information, testing, and engineering that is indicated to have gone into the FlatFix Wave rooftop mounting products, DNV considers Esdec to be an organization which is well funded with strong financial health that, through qualitative design processes and extensive test procedures, is capable to supply suitable mounting systems that do not pose any atypical risks.

7 REFERENCES

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