Seamless-PV

Market trends and regulation for Integrated Photovoltaics: Seamless-PV

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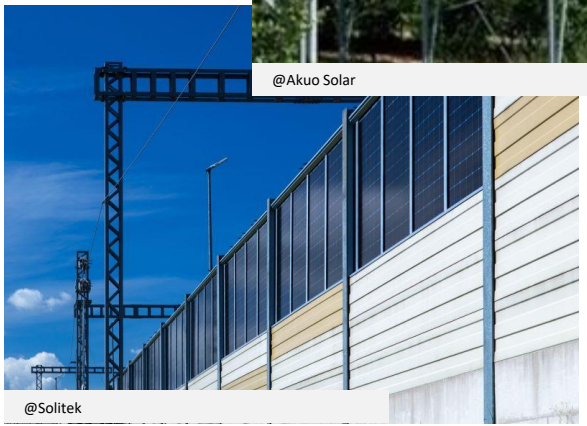
- Dual-functionalty
- Enhanced aesthetics
- Synergies with other sectors


@Onyx Solar


@Akuo Solar


@Solitek

@Fraunhofer ISE

2. BIPV offers a diverse range of applications

Roof applications:

Simplified BIPV

@GSE Intégration

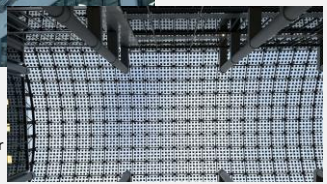
Discontinuous BIPV roofing

@Freesuns

@SunStyle

Skylights

@Onyx Solar



@Metsolar

Façade applications:

Curtain wall façade

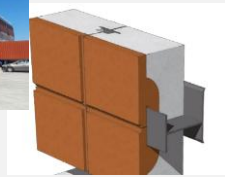
@Onyx Solar

Rainscreen façade

@Solarnova

Insulating façade cladding

@PIZ



Balustrades, balconies and other accessories

@Ertex Solar

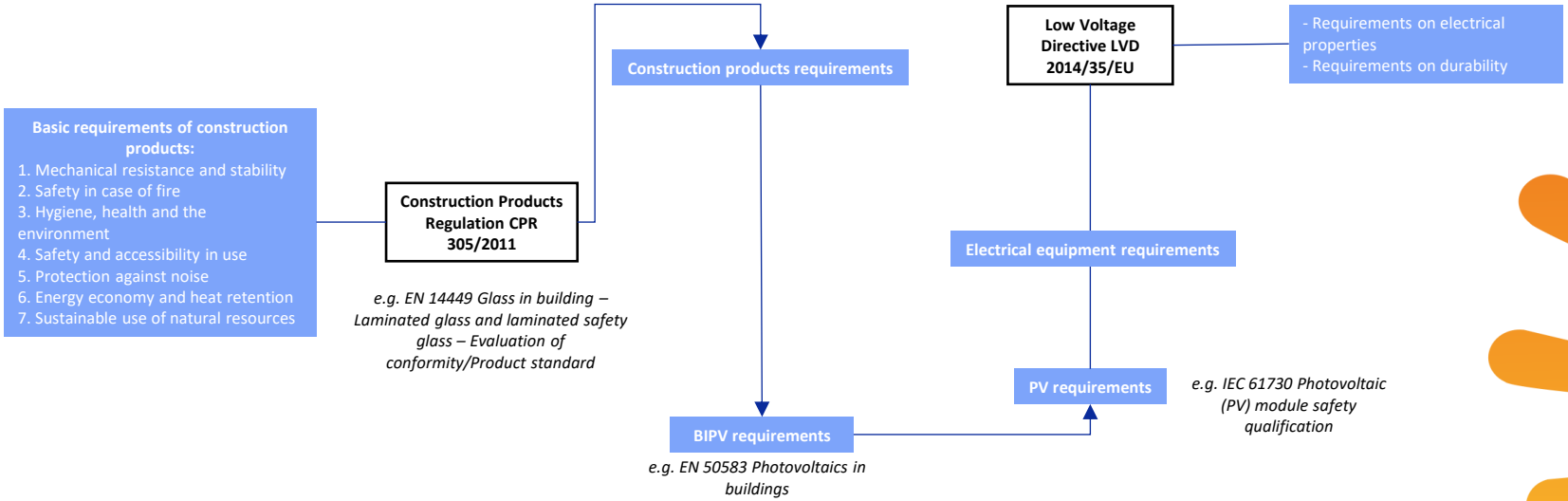
Regulatory framework of BIPV

- **BIPV is covered** under **International** and **European standards**:
  - EN 50583
  - IEC 63092
  - IEC TR 63226

- **BIPV modules** and **systems** are both electrical components and building products, thus it must apply electrical and construction requirements.

Each country's own building renovation and energy requirements also impacts BIPV

Overview of requirements applying to BIPV



Building codes and energy standards can significantly impact BIPV

Denmark: Buildings with a height >22 m request a fire reaction classification A2-s1,d0 which might prevent the use of BIPV.

France: Technical approval (ATEC) is required in practice for building PV systems, as it is necessary for insurance.

- PV is not generally covered by DTUs, an evaluation is needed to prove suitability.
- Strict fire safety class in certain residential buildings may restrict BIPV

Germany: Facades and parapets of high-rise buildings (>22m) demand virtually non-combustible products, which might prevent the use of BIPV.

Switzerland: Certain buildings in Switzerland (particularly facades on high-rise structures) demand A2 fire reaction class, which might prevent the use of BIPV.

Incentives and targets shape BIPV adoption

Direct BIPV incentives

- Financial support, grants, subsidies
- Not common across Europe, but impactful where they exist
- e.g. Switzerland's tilt-angle bonus

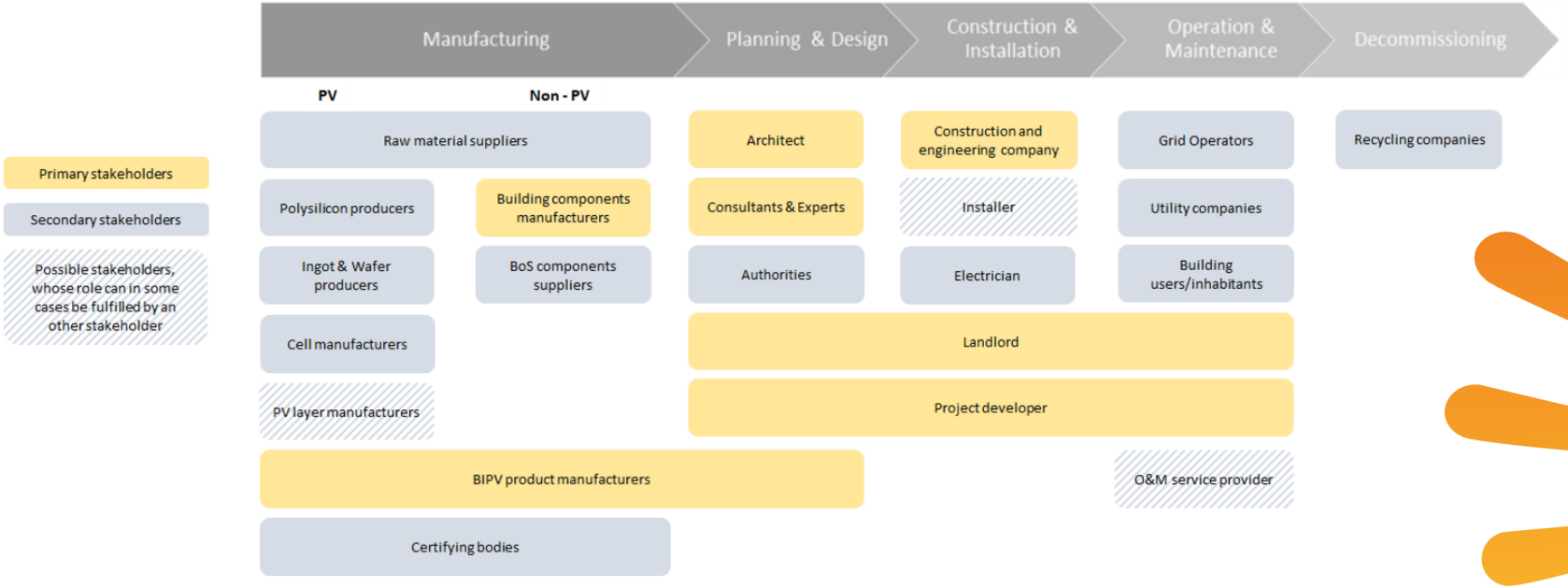
General PV support

- FIT, net metering, investment subsidies
- Most common form of support
- BIPV benefits indirectly

Energy efficiency targets

- NZEB requirements
- Drives the renovation market, which can support BIPV

Key BIPV stakeholders along the value chain



Key BIPV stakeholders' role

	Manufacturing	Planning & Design	Construction & Installation	Operation & Maintenance
Construction product manufacturer				
BIPV product manufacturer	e.g., Produces specific IPV modules for building integration with special module requirements.			
PV layer manufacturer				
Consultant/BIPV expert				
Architect		e.g., Responsible for the delivery of the conceptual project and evaluation of design alternatives. Defines construction guidelines and special module requirements.		
Construction and engineering company			e.g., Construction of the project in accordance with the project conceptualization. Responsible for IPV solution installation.	
Authorities				
Landlord				
Project developer				

Main factors driving BIPV adoption

Economic & regulatory

- Economical motivation
- Incentives & subsidies
- Energy targets

Environmental & innovation

- Sustainability
- Energy targets
- Innovation

Brand & social perception

- Corporate & client image
- Design objectives

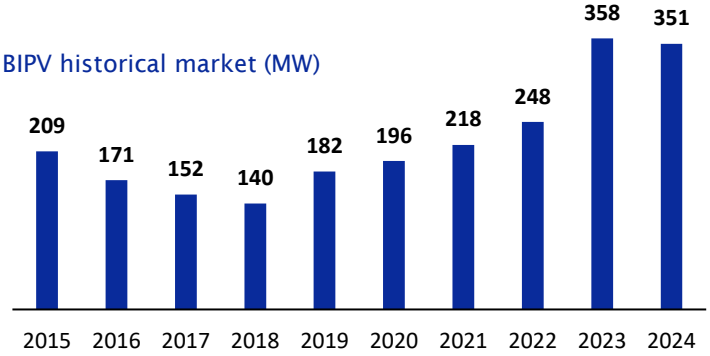
Technical & performance

- Innovation
- Building standards
- Technical superiority of BIPV

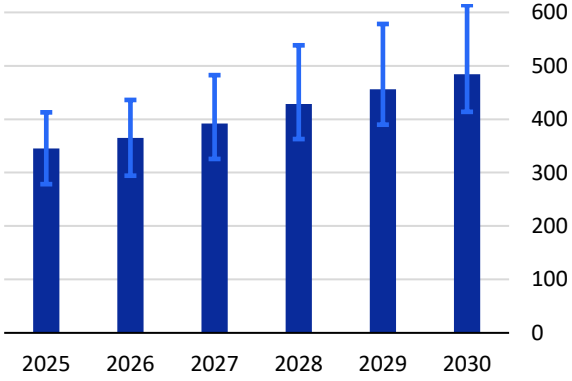
Source: SUPSI

The BIPV market will continue to grow moderately

BIPV historical market (MW)



BIPV market forecast (MW)



BIPV outlook

- BIPV-specific **incentives are rare nowadays**
- **Rooftop BIPV will remain more popular**, but there is a growing interest in façades
- Considering the **general economic and political environment**, no major "market boom" is anticipated in the medium term
- Technical **requirements and standards** are a major barrier in some countries
- Other main obstacles can be mentioned, such as a **limited activity level in the sector of new constructions** or the **phasing out of BIPV support schemes**
- **Renovation activities** in order to meet NZEB targets and "solarization" obligations will be an increasing driver for BIPV growth, although the **competition with other technical systems** will be significant.

2. IIPV (Infrastructure-Integrated PV)

It is the integration of PV on or into infrastructural objects, mantaining the primary functionality of the infrastructural object

@Etway

@Onyx Solar

We will focus on **PV noise-barriers (PVNB)** and **carports**

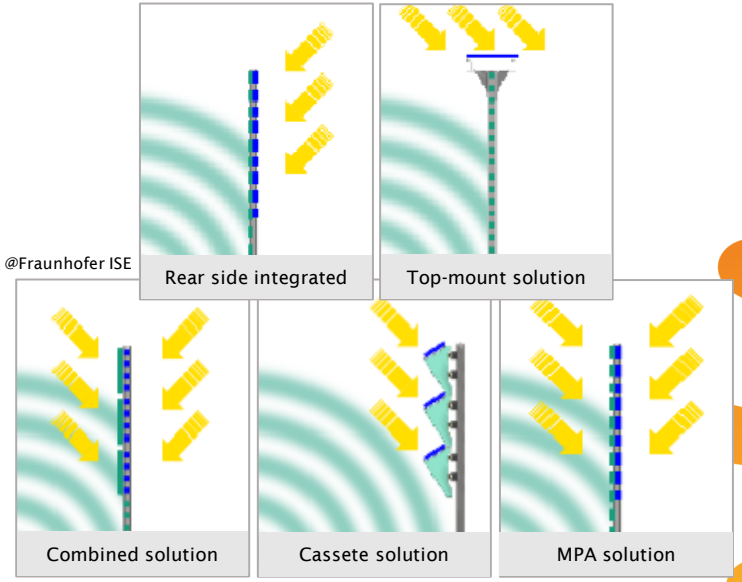
PVNB:

@TNC Consulting

@Solitek

@pvresources

@Fraunhofer ISE

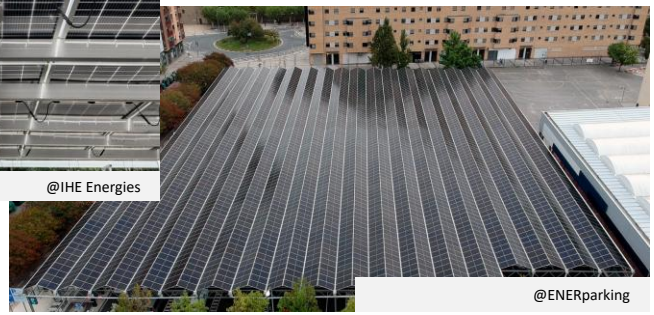


Solar carports:

Commercial

@IHE Energies

@Megasol



@ENERparking

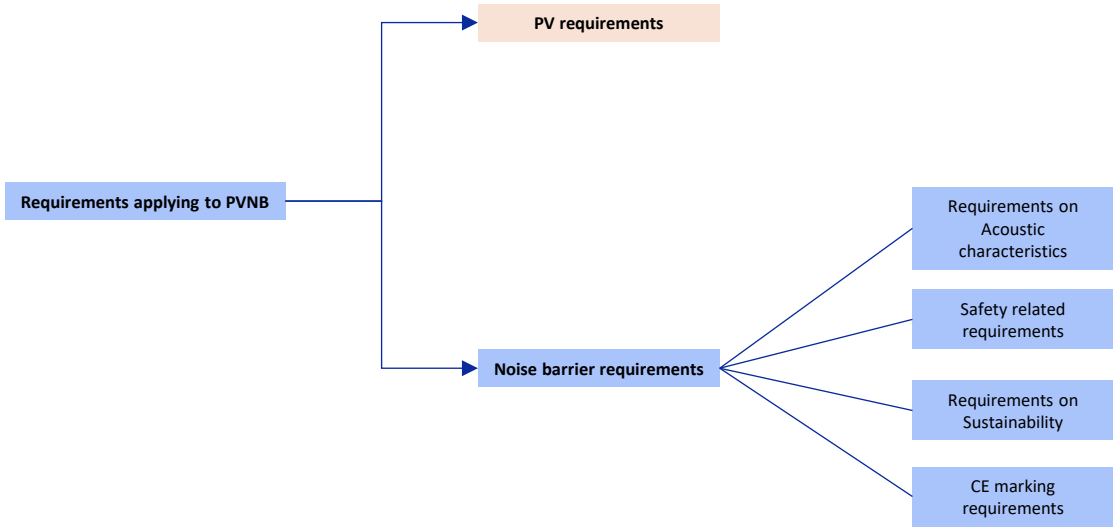
Residential

@ePIT

@Autaq

Regulatory framework of IIPV

- Definitions vary accross countries and IIPV use cases
- **PVNB:**



- **Carports:**

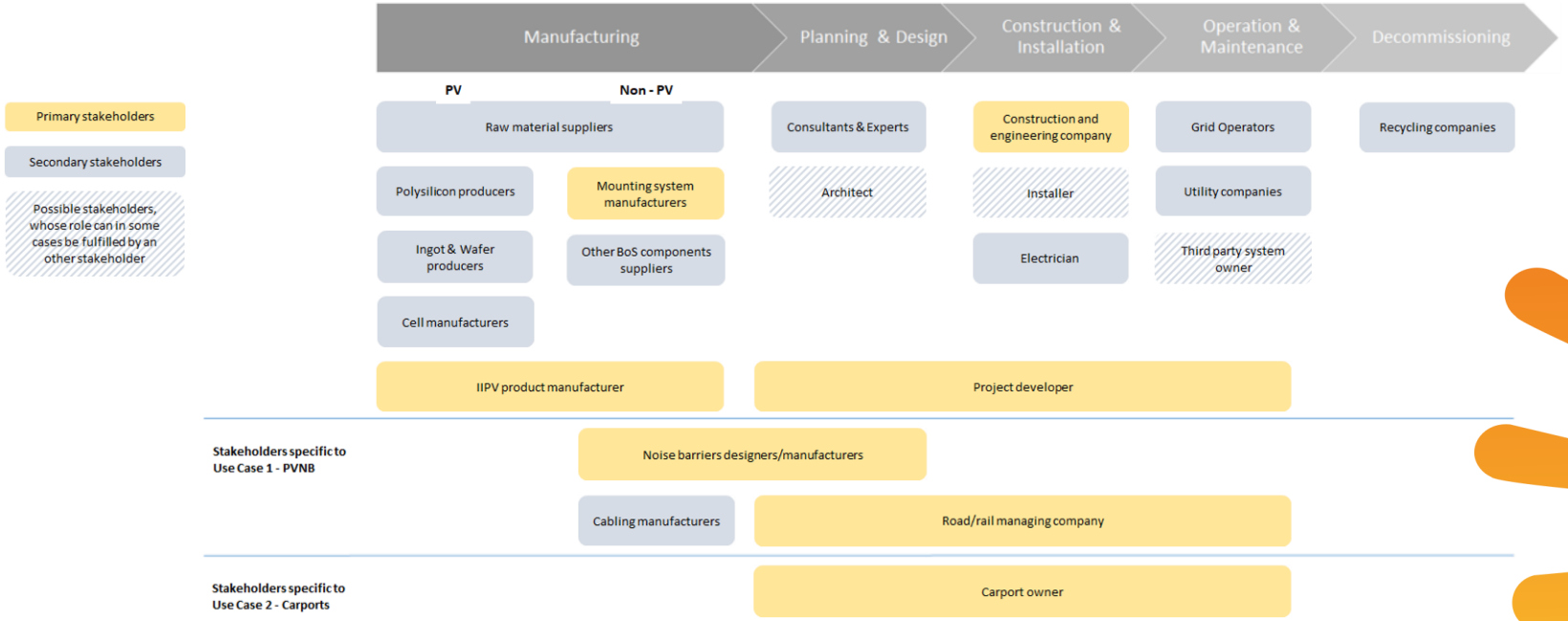
France: Buildings with a height >22 m request a fire reaction classification A2-s1,d0 which might prevent the use of BIPV.

Starting date	Scope	Size threshold	Cover ratio
November 2019	New parking lots, extensions or major refurbishments	1000 m²	30%
July 2023		500 m²	30%
July 2026		500 m²	40%
July 2027		500 m²	50%
January 2028	All existing parking lots	500 m²	To be defined

Germany: Several federal states have introduced requirements for solar on new parking spaces

- **Baden-Württemberg, North Rhine-Westphalia:** Solar carport requirement began in 2022 for parking lots with more than 35 spaces
- **Lower Saxony:** Compulsory PV from 2023 for parking lots with more than 50 spaces
- **Rhineland-Palatinate:** Requirement began in 2023 for parking lots with spaces for more than 50 vehicles. At least 60% of the area should be covered by PV
- **Hesse:** From November 2023, PV is mandatory for new parking spaces with more than 35 (state-owned) or 50 (non-state owned) spaces
- **Schleswig-Holstein:** Since 2023, for newly built parking lots with over 100 spaces

Key IIPV stakeholders along the value chain



Key IIPV stakeholders' role

		Manufacturing	Planning & Design	Construction & Installation	Operation & Maintenance
General Stakeholders	Mounting system manufacturers				
	IIPV product manufacturer	Producing specific IPV modules for infrastructure integration with special module requirements	Participating in the development of tailor-made solutions to assess the feasibility of customer requirements within the manufacturing process and assist designers in selecting the most optimal manufacturing solution		
	Construction and engineering company			Responsible for the construction of the project in alignment with the project conceptualization, including the installation of IPV solutions	
	Project developer		Engaging in the design and creation of a technical model for the IIPV system, including preliminary studies on energy gains and cost considerations		
Stakeholders specific to PVNB	Noise barriers designers / manufacturers	Manufacture standard noise barriers that can be retrofitted with PV or transform into IIPV product manufacturers by producing PVNBs			
	Road / rail managing company				May be accountable for maintenance and ensuring the integrity of the PV system
Stakeholders specific to carports	Carport owner				Assumes responsibility for safeguarding the integrity of the PV system

Main factors driving IIPV adoption

Policy and regulatory motives

- Regional and national mandates in some countries
- Aligns with EU decarbonization and noise reduction targets

Economic and technical aspects

- Proven technologies
- Electricity revenue and possible funding

Mobility trends and land use

- Integration with EV infrastructure
- Utilization of existing infrastructure, preserving natural and agricultural land

IIPV market trends

IIPV market status

- Mature technologies
- **PVNB** remains **highly concentrated in a few countries**, whereas **carports are** only directly **only supported in two**
- Strong **synergy** with **EV infrastructure**
- The **current PVNB capacity** is estimated to be around **15 MW**

IIPV outlook

- **Massive potential** for commercial **carports**
- **Unlike** the massive potential for **vertical PV**, **PVNB's** is **not as significant**
- **Regulatory support** and inclusion of IIPV as part of country's **energy strategies** is key for these technologies to grow

A wide diversity of PV systems in agricultural areas exists

Ground-mounted PV with grazing

©Qenergy - France

©BayWa r.e - France

Ground-mounted PV with agricultural activity in interspace

Vertical bi-facial PV with grazing or agricultural activity in interspace

©Next2Sun - Germany

©Next2Sun - Austria

Elevated PV with tracking (mobile)

©Ombrea - France

©Sun'Agri - France

Elevated PV without tracking

©BayWa r.e - France

©Akuo Energy - France

PV integrated in greenhouses

©Amarenco - France

©Akuo - France

In the different frameworks and support mechanisms, two types of PV projects are considered

- **PV on agricultural area**: PV plants where some form of agricultural production is maintained while energy production dominates

  ⇒ classic competitive tenders or negotiate PPAs

- **Agrivoltaics:** PV plants complying with advanced criteria where they enhance agricultural production and farmer revenue. Agricultural production profitability must dominate, and energy production is an added value.

  => specific subsidies

PV on agricultural areas is authorised in very specific cases only
AgriPV is defined according to four specific criteria

PV on agricultural area	Agri PV
Conditions: • authorised on very specific areas only (uncultivated and unsued for >10 years, close to buildings, abandoned areas, …)	Conditions: ▪ Agricultural activity = primary land use (in terms of area) ▪ Significant agricultural production (>90% of regular agriculture) ▪ Service provided to agriculture (agronomic improvement, adaptation to climate change, protection against risks and hazards, animal welfare improvement, …) ▪ Reversibility
No specific subsidies	Specific subsidies

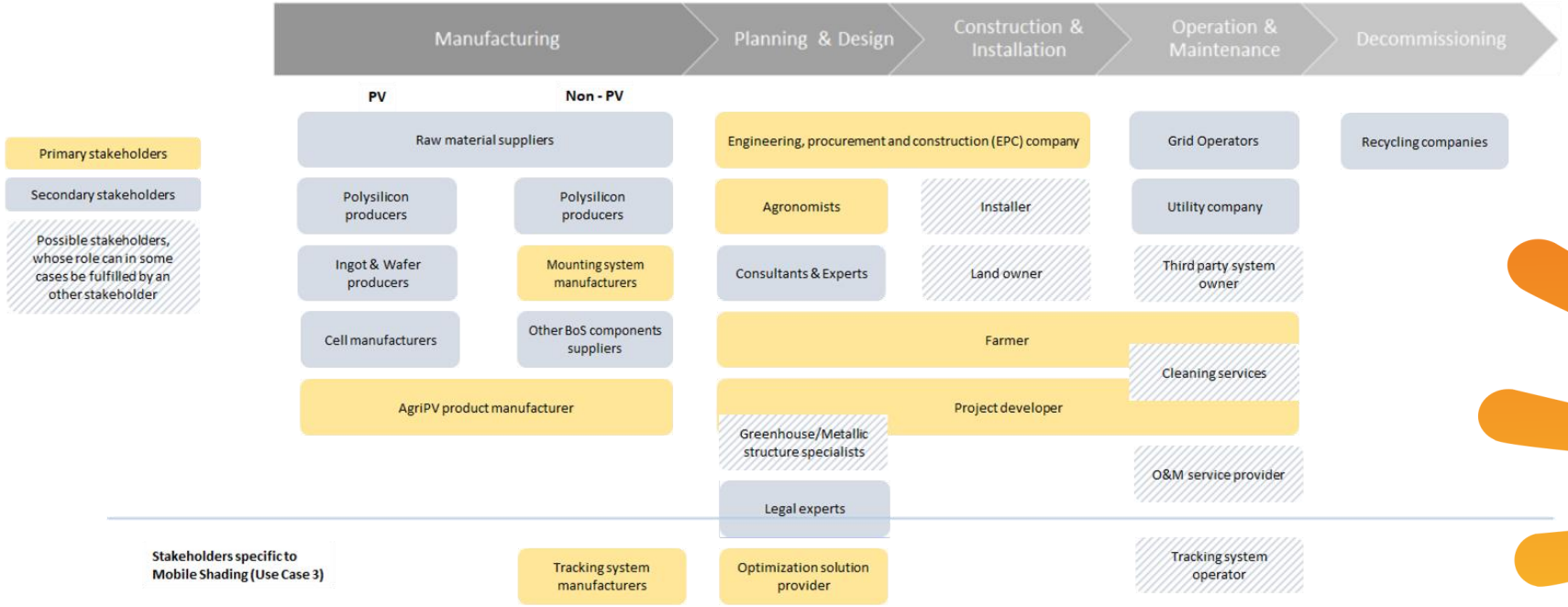
Loi n° 2023-175 du 10 mars 2023 relative à l'accélération de la production d'énergies renouvelables (« APER »)
Décret n° 2024-318 du 8 avril 2024 relatif au développement de l'agrivoltaïsme et aux conditions d'implantation des installations photovoltaïques sur des terrains agricoles, naturels ou forestiers

PV on agricultural areas is authorised in very specific cases only
Two AgriPV definitions based on specific criteria exist.

PV on agricultural area	Agri PV	Advanced Agri PV
Prohibited except: • on very specific areas only (areas near industrial or road infrastructure, or belonging to railway, highway, or airport infrastructure operators, abandoned lands, former mines, or quarries, …)	Conditions: ▪ Agricultural activity = primary land use (>70% in terms of area) ▪ Solar module coverage rate <40% ▪ Significant PV production (>60% of regular PV) ▪ Maintained agricultural production	Conditions: ▪ Agricultural activity = primary land use (>70% in terms of area) ▪ Solar module coverage rate <40% ▪ Significant PV production (>60% of regular PV) ▪ Maintained agricultural production ▪ Minimum height (e.g., 2.1m for crops) ▪ Regular impact monitoring (water, soil fertility, climate change resilience, …)
No specific subsidies	No specific subsidies	Specific subsidies

Decreto-Legge n. 63/2024 (in vigore dal 16/05/2024) – Disposizioni urgenti a favore delle imprese agricole, della pesca, dell'acquacoltura e delle imprese di interesse strategico nazionale
Decreto Ministeriale n. 436/2023 del 22 dicembre 2023 – Meccanismo di sostegno per l'agrivoltaico innovativo
Linee guida per gli impianti agrivoltaici (CREA-GSE, 2022)

Key agri-PV stakeholders along the value chain



Key agri-PV stakeholders' role

	Manufacturing	Planning & Design	Construction & Installation	Operation & Maintenance
Mounting system manufacturers				
AgriPV product manufacturer	e.g., manufacturing specific IPV modules for AgriPV projects with project-specific requirements			
Agronomist			e.g., ensure adherence to project expectations and preventing alterations that could jeopardize agricultural production	
EPC				
Farmer		e.g., playing a role in the conceptualization and development of projects that align with their work		
Project developer				

Main factors driving the agriPV market

Strategic & economic motives

- Adaptation to climate change (AgriPV following specific criteria only)
- Diversification of revenue streams (AgriPV following specific criteria only)

Policy & market

- Energy targets (competition for land use)
- Incentives & subsidies

Design & technical drivers

- Innovative systems
- Wide variety of available configurations
- Mature technologies

AgriPV market trends

APV market status

- At least 2.8 GW of agriPV projects as of 2023 and including all types of PV on agricultural areas.

- In Italy, in December 2024, 1.5 GW of agriPV capacity was awarded in the dedicated tender. A second round is running until June 2025.
- In Germany, it is estimated that by the end of 2024, there was around 400 MW of installed capacity.
- In France, the regulatory framework established in 2023 and 2024 will serve as the cornerstone of the agrivoltaic sector, providing structure and driving the development of numerous projects currently in the pipeline.

APV outlook

- AgriPV is expected to take off as it becomes increasingly acknowledged as key in a high competition for land context

- Sound and specific regulation for agriPV is key in mitigating concerns, increasing social acceptance, and promoting agriPV systems which allow for a balance between both activities.

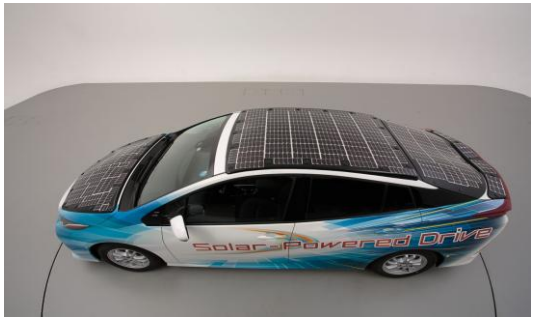
- The market potential of agriPV is significant
- Even with a strict regulation scenario, the cumulative installed capacity of AgriPV could reach 1 TWp in 2050

VIPV can take various forms

Passenger cars

- Primarily employed in hybrid and electric vehicles
- PV integration primarily concentrated on the mostly flat rooftop (panoramic sunroof, or broader integration)
- PV integration in curved areas poses some challenges
- Low area available for integration
- Shading in dense urban environment

Lightyear



Toyota Prius

Sono (terminated program)

AGC Automotive Europe (panoramic sunroof)

VIPV can take various forms

Commercial vehicles

- Integration also common in non-electric vehicles (e.g., refrigerated) and as retrofit action
- Presence of more horizontal and flat surfaces
- Importance of aesthetics is relatively lower
- Higher area available for integration
- Shading in dense urban environment

Solarontop by IM Efficiency


DHL

Fraunhofer ISE

VIPV can take various forms

Buses

- Integration also common in non-electric vehicles (e.g., air conditioning, ventilation and on-board appliances) and as retrofit action
- Presence of more horizontal and flat surfaces
- Importance of aesthetics is relatively lower
- Higher area available for integration
- Shading in dense urban environment

Munich Transport Company's diesel bus

Flixbus diesel bus

SonoMotors Retrofit solution

VIPV regulation

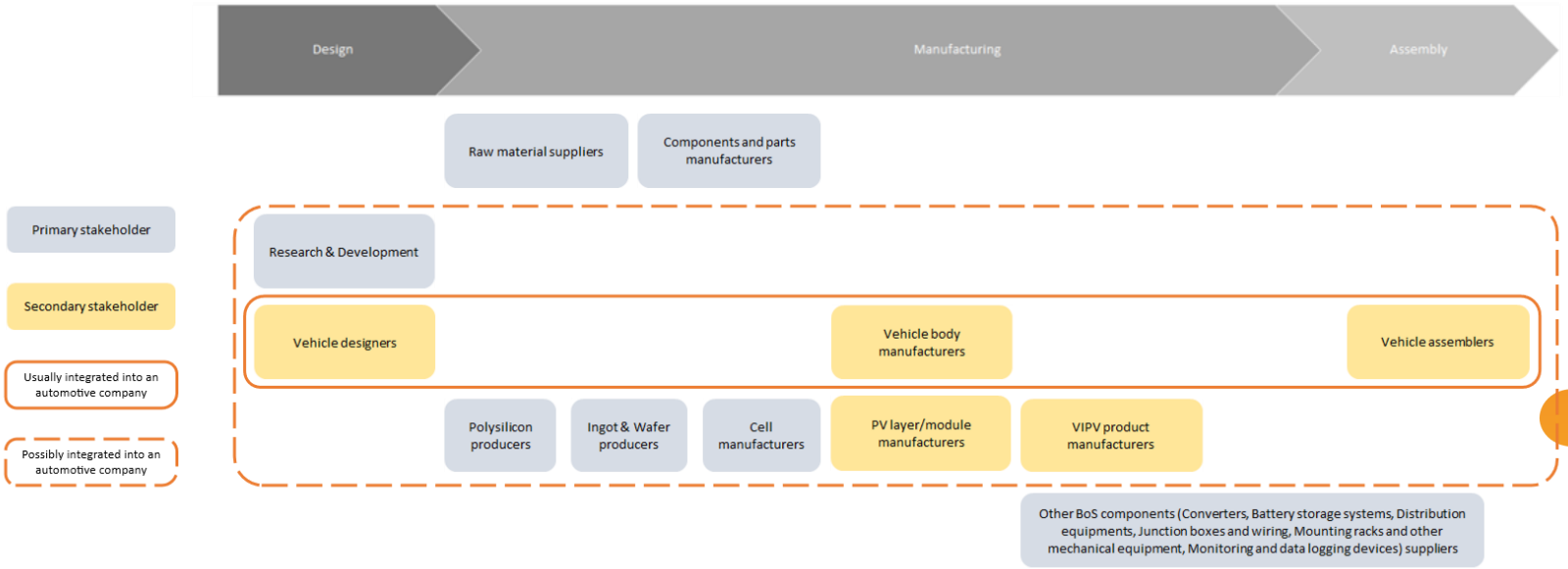
Little to no definitions, regulations or incentives specific to VIPV exist.

- The IEC is developing standards for vehicle-integrated photovoltaic (VIPV) systems
- This standard will address test procedures, performance metrics, durability, and safety criteria specific to VIPV systems.

Several policies and directives are aimed at (electric) vehicles (EVs) and could in turn drive VIPV technologies

- Regulation 661/2009 - requirements for motor vehicles and their trailers.
- Regulation (EU) 2018/858 - safety, environmental performance, and quality of vehicles sold
- Regulation (EU) 2023/851 - CO_2 emission performance standards for new passenger cars and new light commercial vehicles.
- Regulation (EU) 2024/1610 - CO_2 emission performance standards for heavy-duty vehicles.

Key VIPV stakeholders along the value chain



Key VIPV stakeholders' role

	Design	Manufacturing	Assembly
Vehicle designers	Enabling PV integration into vehicle design. Collaborating with R&D for PV integration in more challenging vehicle parts		
Polymer solar panel manufacturers			
Vehicle body manufacturers			
VIPV product manufacturers		Manufacturing distinct VIPV products to match the brand, model, and car colour. Offering these products for sale to vehicle body manufacturers	
Vehicle assemblers			Assembling the vehicle, including IPV parts

Main factors driving the VIPV market

Strategic & economic motives

- Corporate image, differentiation strategy
- Sustainability

Policy & market

- EV market dynamics
- Emission targets and policies

Design & technical drivers

- Extended driving ranges
- Premium feature

VIPV market trends

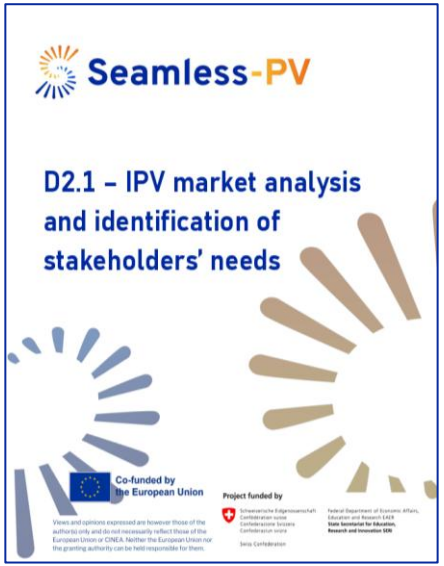
VIPV market status

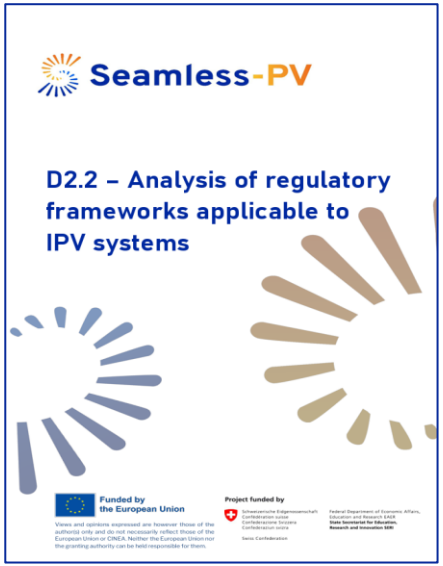
- The market is virtually inexistent
- The sector still faces significant barriers.
  - High production costs for specialized solar modules
  - Technical complexity in vehicle integration
  - Increasing EV ranges (battery energy density improvement, ultra-fast charging stations, …)
  - Benefits can be difficult to estimate as driving patterns are very diverse (passenger cars)

VIPV outlook

- Light EVs: vast majority of the potential (greatest number of vehicles and an already established EV market)
- Light Commercial EVs: second most promising segment (greater surface area than LEVS, relatively large fleets, combination with retrofit & ICE vehicles possible)

Available publications





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Thank you!

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