Agrivoltaics: International Development, Legal and Economic Aspects

Electrical Installations National Congress

Izmir

Nov 01, 2023

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International Development of Agrivoltaics

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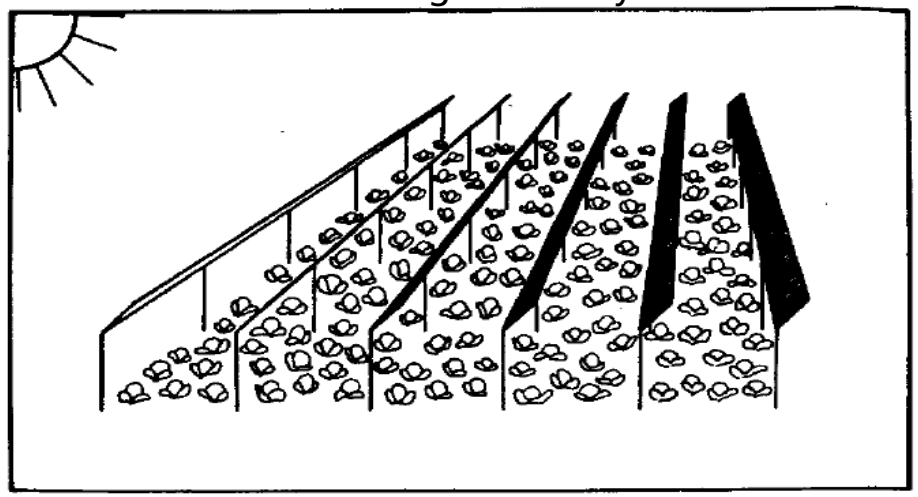
Development of agrivoltaics

Origins: A. Goetzberger, Founder of Fraunhofer ISE and A. Zastrow (1981)

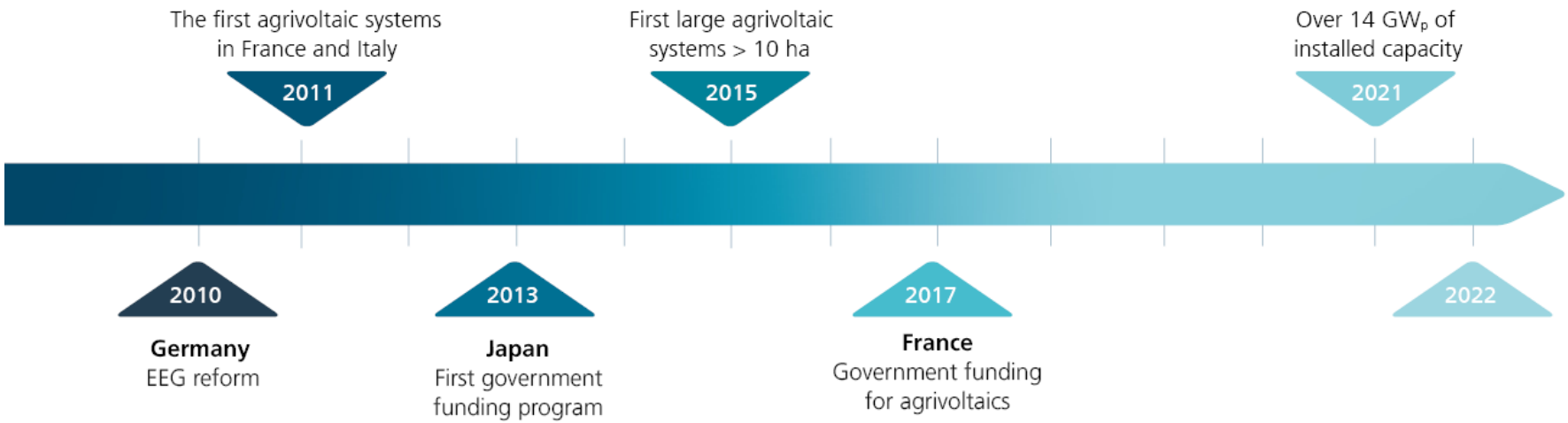
Adolf Goetzberger, first director of Fraunofer ISE

First illustration of an agrivoltaic system



Source: Goetzberger und Zastrow (1981)

Development of agrivoltaics since 2010



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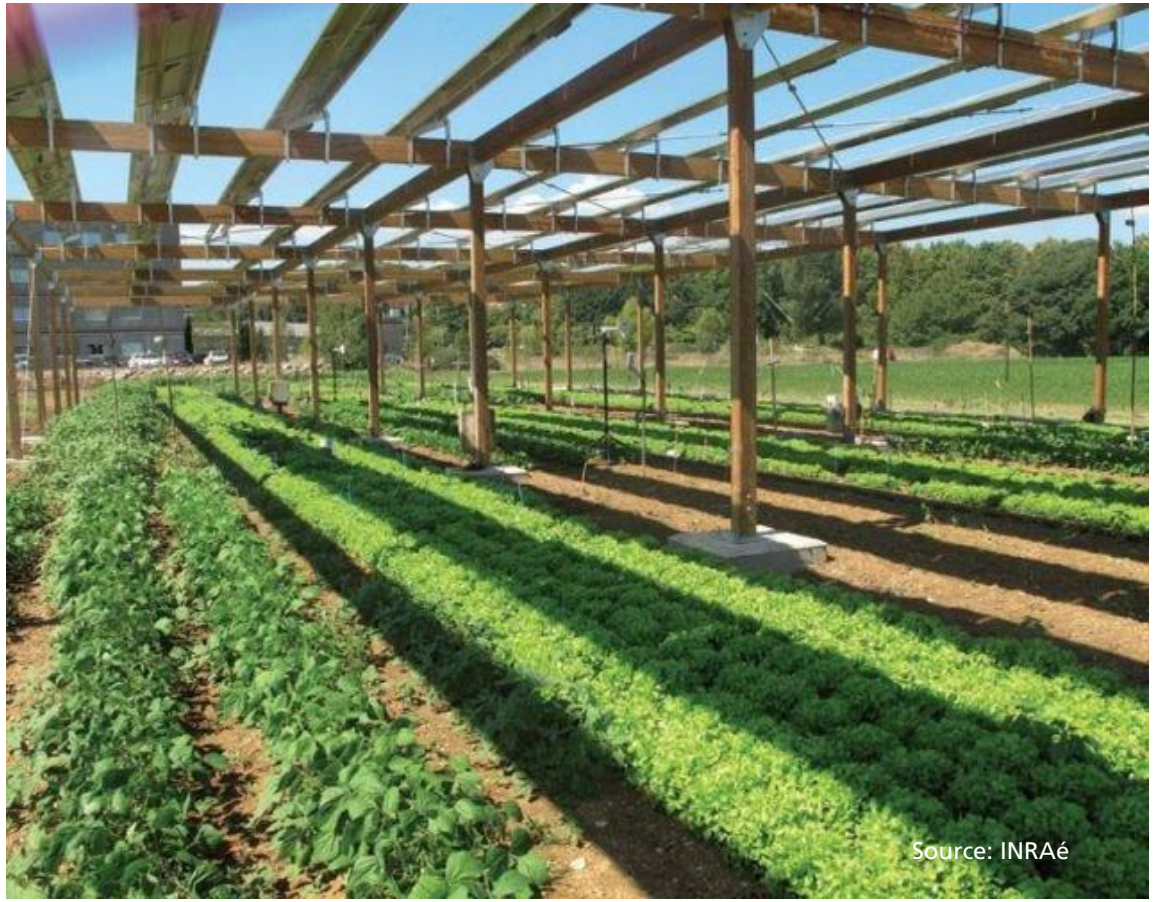
Diversity of Agrivoltaics



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Diversity of Agrivoltaics

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Diversity of Agrivoltaics


Source: Oregon State Universtiy, Mark Floyd


Source: Next2Sun

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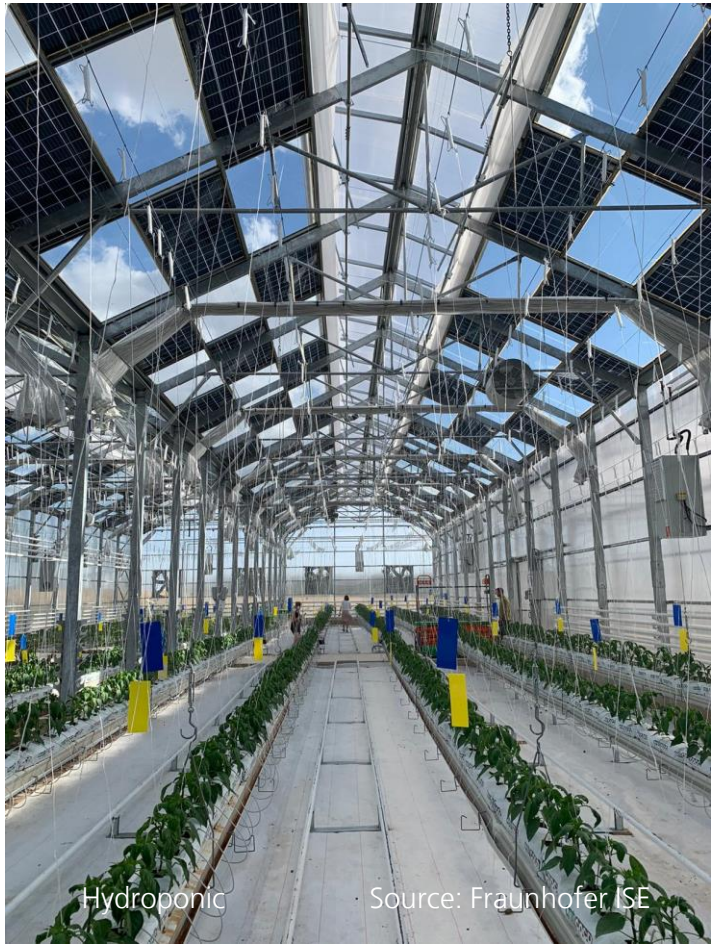
International Development of Agrivoltaics

Diversity of Agrivoltaics



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Research Results of Fraunhofer ISE

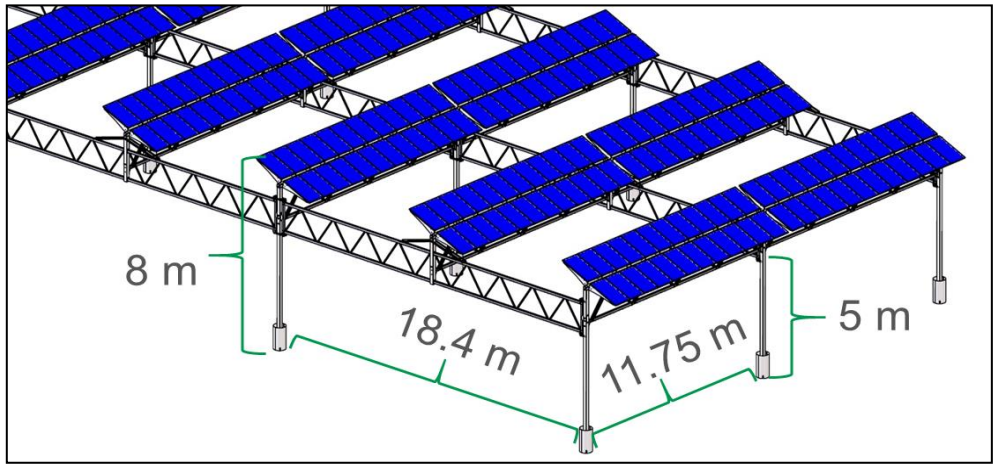
APV-RESOLA

First pilot in arable farming in Germany

Project duration: March 2015 – July 2021

Topic: Field trials on clover grass, potato, winter wheat and celery

Installed capacity: 194 kWp



Source: Hilber Solar

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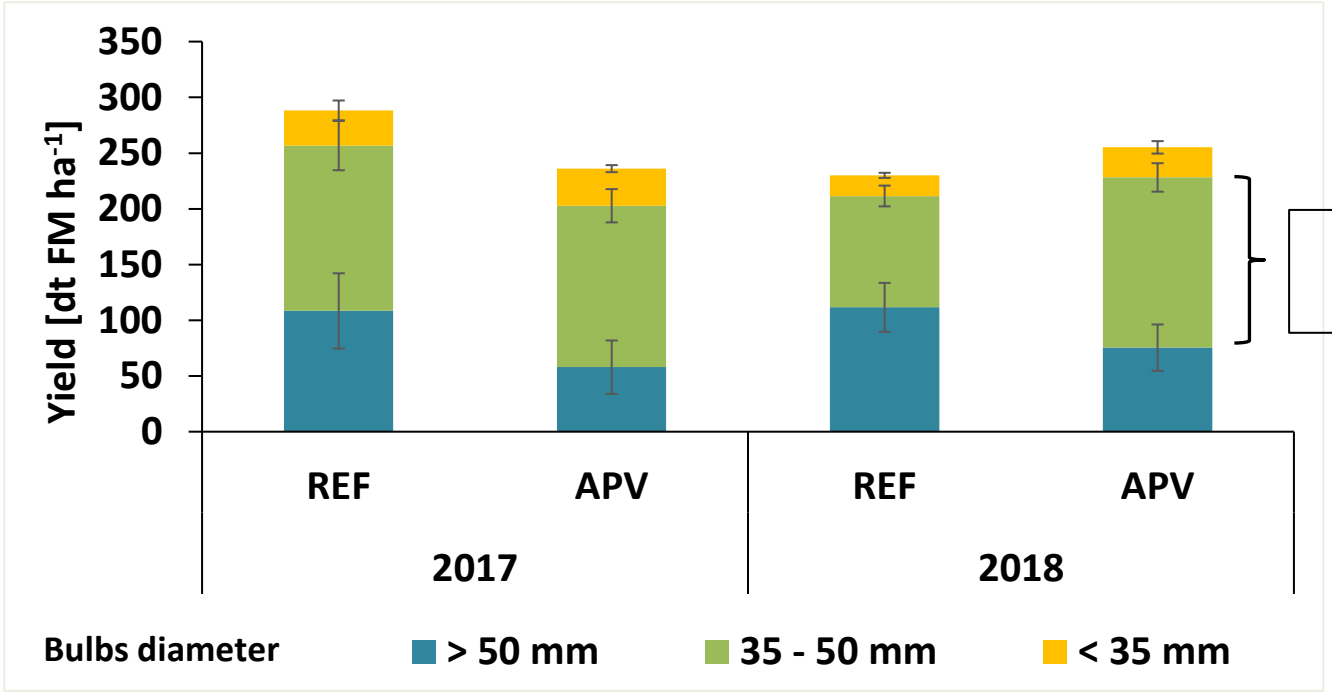
APV-RESOLA

First pilot in arable farming in Germany



Source:
Universität Hohenheim


Source: Universität Hohenheim


Source: Hofgemeinschaft Heggelbach

- 2017: Yield under APV reduced by 18 %
- 2018: Yield under APV increased by 11 %
- Higher share of bulbs with diameter 35 - 50 mm under APV in both harvests

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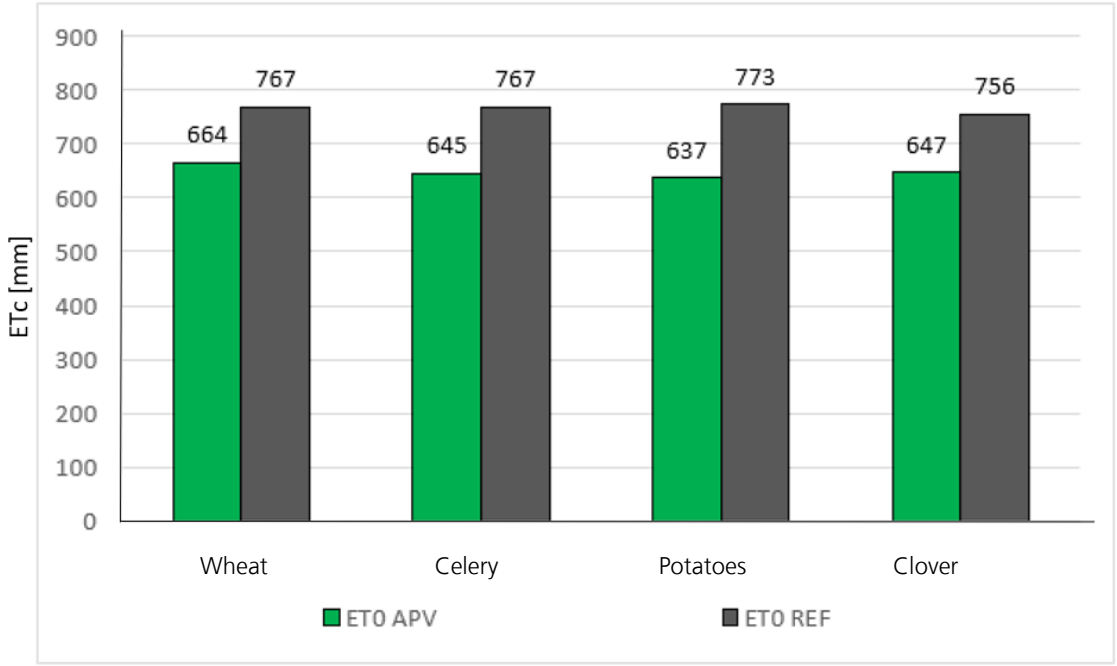
APV-RESOLA

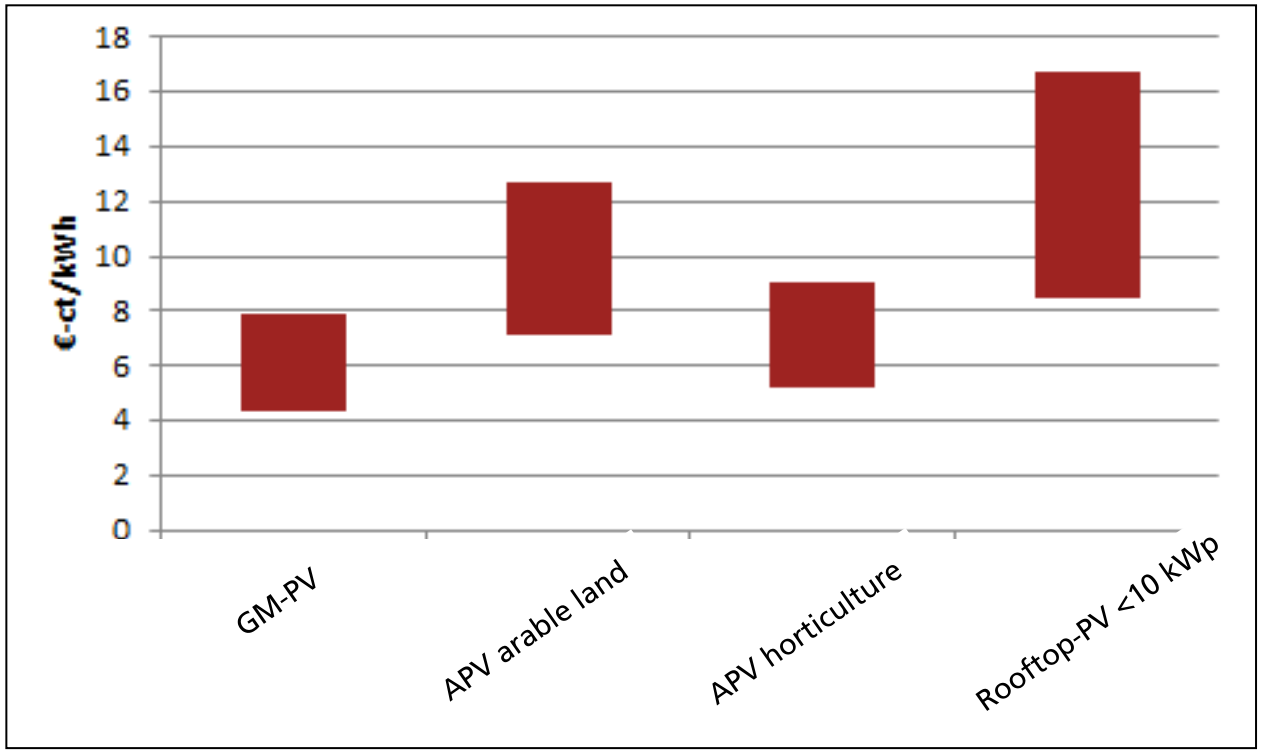
First pilot in arable farming in Germany

- Reduced soil temperature on the agrivoltaics surface.
- Reduction of evapotranspiration (evaporation)



Economy : PV-Power Generation Cost

Estimated average levelized cost of electricity [€-ct/kWh]



- Electricity from agrivoltaics about 20 % cheaper compared to small rooftop systems
- In arable farming generation of electricity costs 20% more than on grassland
- Electricity from ground-mounted systems is still the most cost efficient

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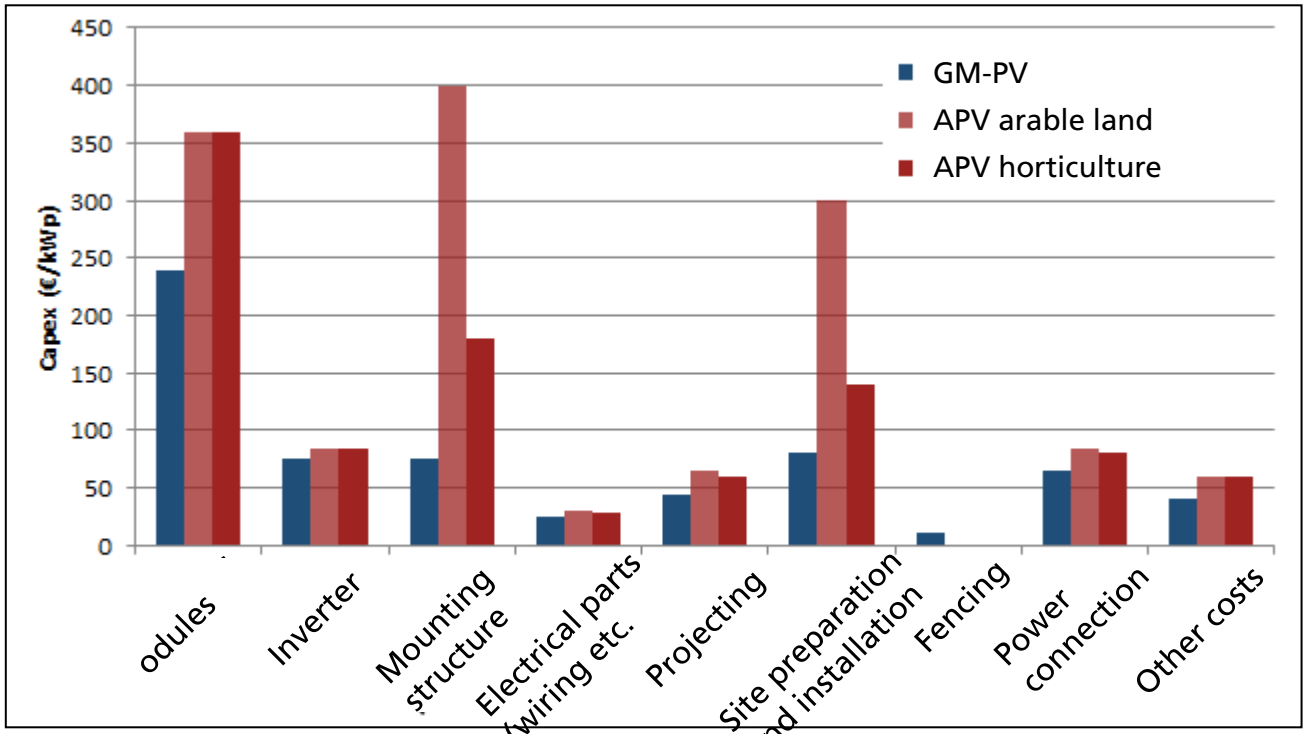
Economy: Capital Expenditure

Capital expenditure [€/kWp]



- Economic viability is a major factor for agriculture
- Differences in investment costs mainly:
  - Mounting structure
  - Module price
  - Site preparation and installation
- Costs for electrical components and planning in most cases comparable to ground-mounted PV systems

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WATERMED4.0

Efficient use and management of water resources through smart technologies

Project duration: June 2019 – Dec 2022

Topic: Management of the water cycle in agriculture and measure of economic, energy, social and governance factors that influence the water use efficiency in Mediterranean (Algeria) agricultural production areas.

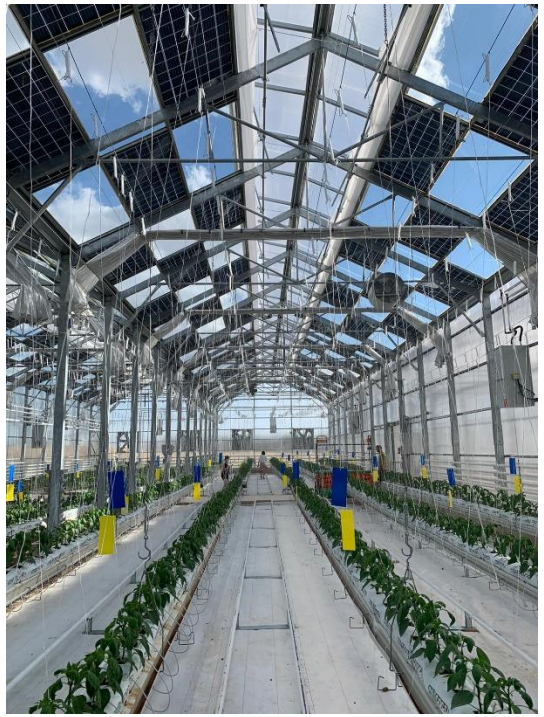
Installed capacity: 10 kWp

Technology: V-Shaped rainwater harvesting

SusMedHouse

Sustainable Mediterrenian Greenhouse

Project duration: January 2020 – June 2023
Topic: : Efficient, eco-friendly, sustainable Mediterranean greenhouse with integrated artificial intelligence, hi-tech automation and control system
Installed capacity: 48,6 kWp
Approach: Evaluation of light distribution effects on PV greenhouse plant development for horticultural cultivars (tomato, lettuce, pepper). Phenotypic monitoring and analysis via image correlation



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Standards and Legislation of Agrivoltaics

Agrivoltaics: Standards and Legislation

German DIN SPEC 91434: New German Standard for Agrivoltaics

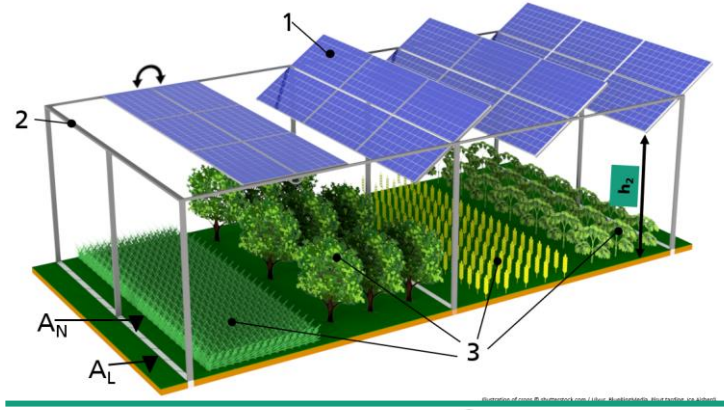
Definition of agrivoltaics according to DIN SPEC 91434:

“Agrivoltaics is the combined use of the same land area for agricultural production as the primary use and for electricity PV production as the secondary use.”

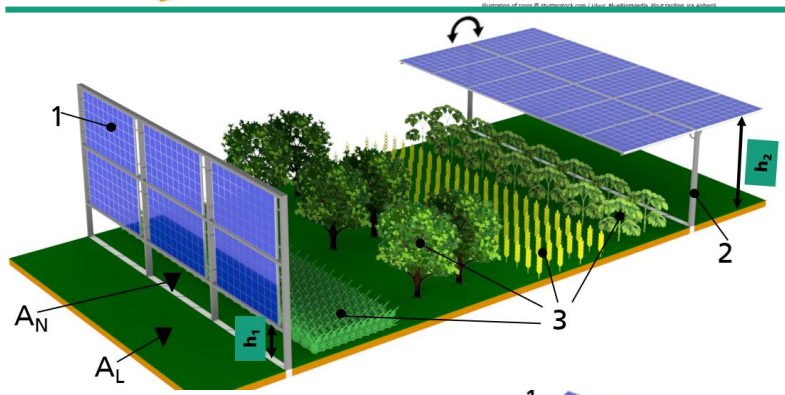
Agrivoltaics: Standards and Legislation

DIN SPEC 91434

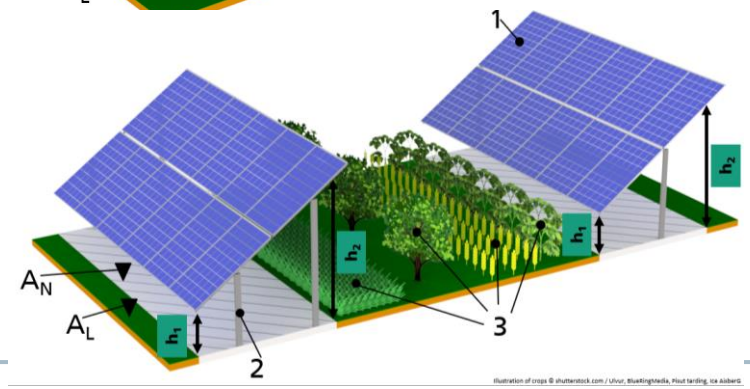
Agrivoltaic System	Use	Example
Category I: Overheads tilted (clearance height >2.1 m)	1A: Permanent and multi-year crops	Fruits, berries, viticulture, hops
	1B: Single-year und long-term crops	Arable crops, vegetables, alternating grassland, fodder
	1C: Grassland with mowing	Intensive and extensive commercial grassland
	1D: Grassland with pasture	Pasture, pasture rotation (e.g. cattle, poultry, sheep, pig, and goat)
Category II: Interspace (clearance height < 2.1 m)	2A: Permanent and multi-year crops	Fruits, berries, viticulture, hops
	2B: Single-year and long-term crops	Arable crops, vegetables, alternating grassland, fodder
	2C: Grassland with mowing	Intensive and extensive commercial grassland
	2D: Grassland with pasture	Pasture, pasture rotation (e.g. cattle, poultry, sheep, pig, and goat)



Cat. I



Cat. 2



Legend:

A_L - Cultivatable agricultural areas

A_N - Uncultivatable agricultural area

H_1 - Clearance height below 2.10 m

H_2 - Clearance height above 2.10 m

1 - Examples of solar modules

2 - Mounting structure

3 - Examples of crops

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Agrivoltaics: Standards and Legislation

DIN SPEC 91434

Core requirements & criteria

- Agricultural yield **at least 66%** to the reference yield
- **Agricultural usability** of the area must be guaranteed (agricultural use concept)
- **Loss of area** due to installation of the system **maximum 10%** (Cat. I) or **15%** (Cat. II)
- **Adapted** to agricultural needs:
  - Adequate **light availability and homogeneity**, and **water availability**
  - **Prevent soil erosion and damage** (structure, anchoring, water management)

Agrivoltaics: Standards and Legislation

Current developments in Germany

Key Issues Paper BMWK, BMUV and BMEL

"Expansion of photovoltaics on open spaces in harmony with agricultural use and nature conservation" of February 10, 2022.

- **EEG 2023, Osterpaket**
- Permanent grassland included
- Distinction between elevated and ground-mounted systems, see technology premium of 1.2 cents/kWh
- Inheritance law: tax benefits for majority-owned agrivoltaic plants
- EU direct payments: from 2023, entitlement to 85% of the area premium

Agrivoltaics: Standards and Legislation

French Legislation

- The three criteria evaluated for the characterization of an agrivoltaic project are:
  - **Criterion 1 Contribution to the agricultural production**
    - The PV systems must have a justified and proven direct contribution to the agricultural production (e.g. protection of crops, welfare of animals, etc.);
  - **Criterion 2 Incidence on agricultural yields**
    - The PV system must increase, maintain or decrease within acceptable proportions the agricultural yield
  - **Criterion 3 Incidence on the revenues of the farm owner**
    - The PV system must improve the farmer's income

European Commission, Joint Research Centre, Chatzipanagi, A., Taylor, N., Jaeger-Waldau, , *Overview of the potential and challenges for agri-photovoltaics in the European Union* – , Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2760/208702

Agrivoltaics: Standards and Legislation

Italian Legislation

- Guidelines on Agri-PV systems was published in June 2022 by the Italian Ministry of the Environment and Energy Security (MITE, 2022). This has four main categories of requirements for Agri-PV projects:

- **Requirement A: The definition of agrivoltaics**
  - Percentage of area covered with PV modules less than 40 %.
- **Requirement B: The synergy between the production of energy and the production of agricultural yield**
  - Electricity production by the Agri-PV system more than 60 % of the electricity produced by a standard PV system.
  - Continuity of the agricultural activity
- **Requirement C: The Agri-PV system adopts innovative integrated solutions with modules raised off the ground**
  - Type 1 Inclined PV modules overhead;
  - Type 2 Inclined PV modules between the crops
  - Type 3 Vertical PV modules between the crops.
- **Requirement D and E: Monitoring systems**

European Commission, Joint Research Centre, Chatzipanagi, A., Taylor, N., Jaeger-Waldau, , *Overview of the potential and challenges for agri-photovoltaics in the European Union* – , Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2760/208702

Agrivoltaics: Standards and Legislation

Definitions of Agrivoltaics, Japan: Agricultural parameters (MAFF)

Agricultural requirements for agrivoltaics

- Criteria set by Ministry of Agriculture, Forestry, and Fisheries (MAFF)
- 80% minimum agricultural yield compared to standard agriculture
- Mandatory annual report including:
  - -agricultural yield
  - -harvest quality
  - -sales slip etc.

https://www.insic.it/tutela-ambientale/energia-e-sostenibilita-articoli/impianti-agrivoltaici-linee-guida-mite-alle-caratteristiche-minime-e-agli-incentivi-pnrr/

Agrivoltaics: Standards and Legislation

Definitions of Agrivoltaics, Summary of Germany, Italy, Japan, and France

Common features in Germany, Italy, Japan, and France

Agrivoltaics must not hinder agricultural production

https://www.insic.it/tutela-ambientale/energia-e-sostenibilita-articoli/impianti-agrivoltaici-linee-guida-mite-alle-caratteristiche-minime-e-agli-incentivi-pnrr/

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Thank you for your attention!





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