Erfahrungswerte aus der Agri-PV-Projektentwicklung

PV auf Agrarflächen im Einklang mit Landwirtschaft und Naturschutz

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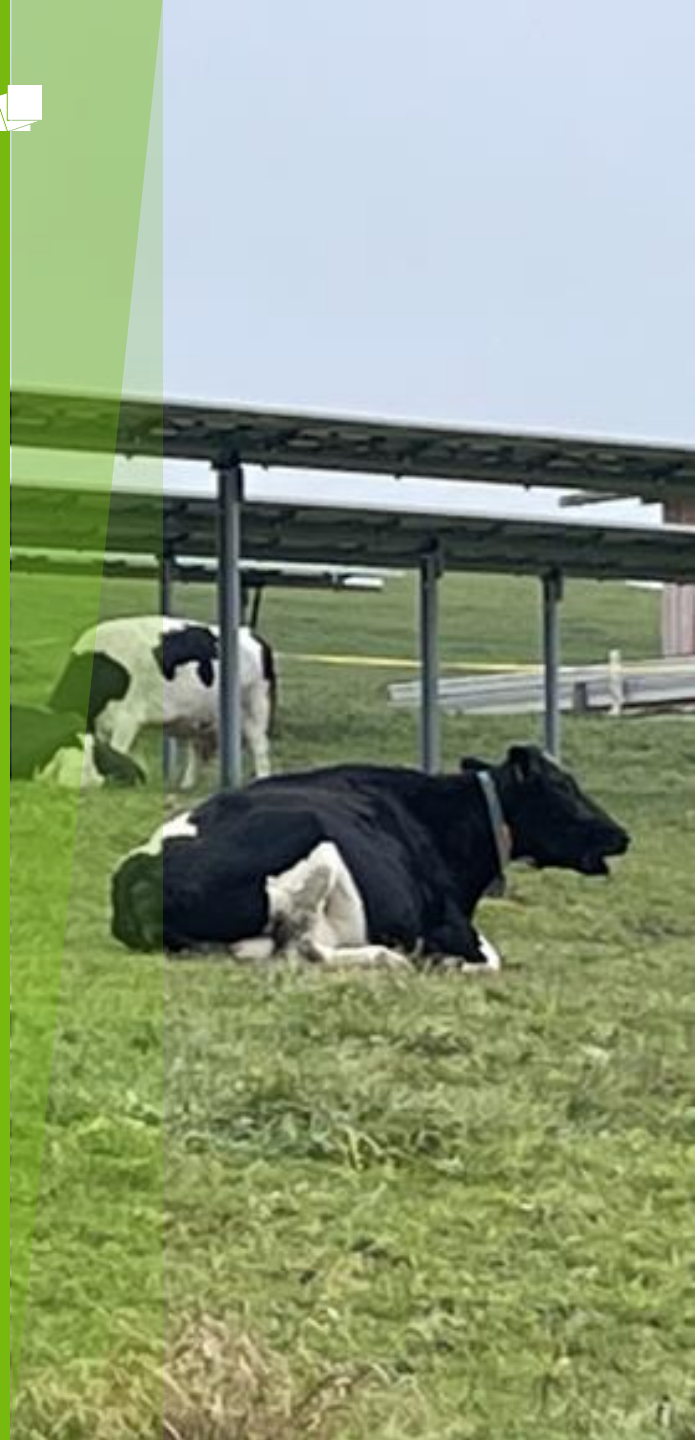
r.e. think energy

Agenda

1. Definition of Agri-Photovoltaics (Agri-PV)
2. Learning by Doing: Agri-PV References by BayWa r.e.
3. The Future (of Utility-scale PV) is Agri-PV



1

Definition of Agri-Photovoltaics (Agri-PV)

Our five pillars in the field of solar project development

Conventional Ground-Mounted-PV

Mono use of conversion site or special zone

Rooftop-PV

Double use of the roof areas

Carport-PV

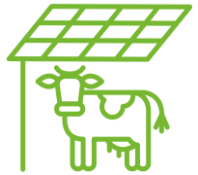
Double use of parking space

Floating-PV

Double use of water surface

Agri-PV

Double use of farmland



Lowest LCOE !

Integrated-PV:
Enable techno-ecological & macro-economic synergies, but are more costly on micro/project level !

Where does the idea of combining PV with agriculture come from?

1981,“ Kartoffeln unter dem Kollektor“, Adolf Goetzberger and Armin Zastrow (Fraunhofer ISE)

- “Livestock farming could also be very attractive in some regions. Sheep, deer or even cattle could be grazed there, if only the substructure of the collector is made stable enough.”

1928 - 2023

1981, Sonnenenergie, 3/81

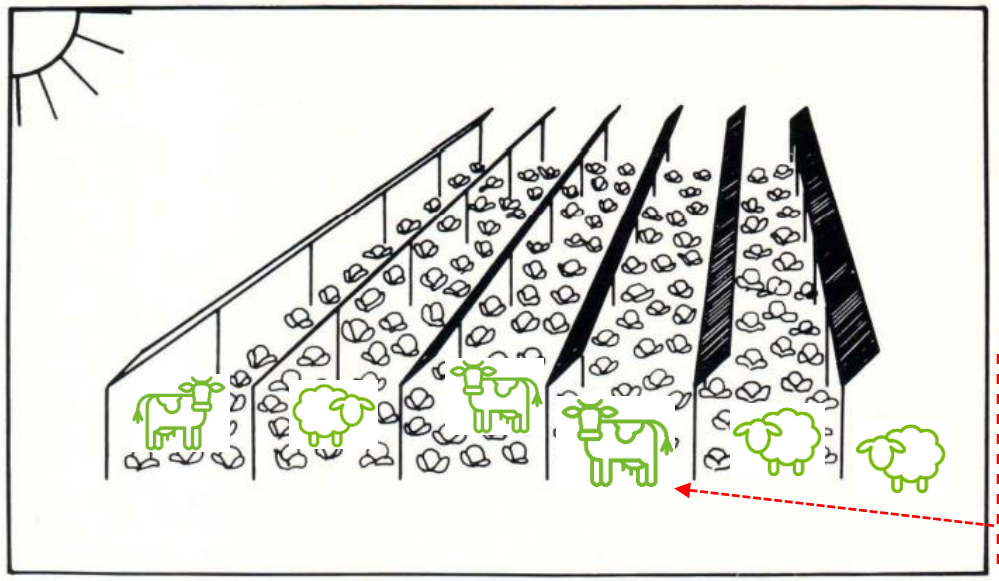


ABB. 1 SKIZZE EINES KOLLEKTORFELDES *mit angehobenen Kollektoren*

Neuer Vorschlag der Fraunhofer-Gesellschaft

Kartoffeln unter dem Kollektor

Pflanzen, die mit den Kollektoren koexistieren könnten, sind dagegen Roggen, Hafer, Gerste und speziell Zuckerrüben. Sehr attraktiv könnte in manchen Gegenden auch die Viehzucht sein; so könnte man Schafe, Wild oder sogar Rinder dort weiden lassen, wenn nur die Kollektorstruktur stabil genug gemacht wird. ●

Definition of Agri-PV

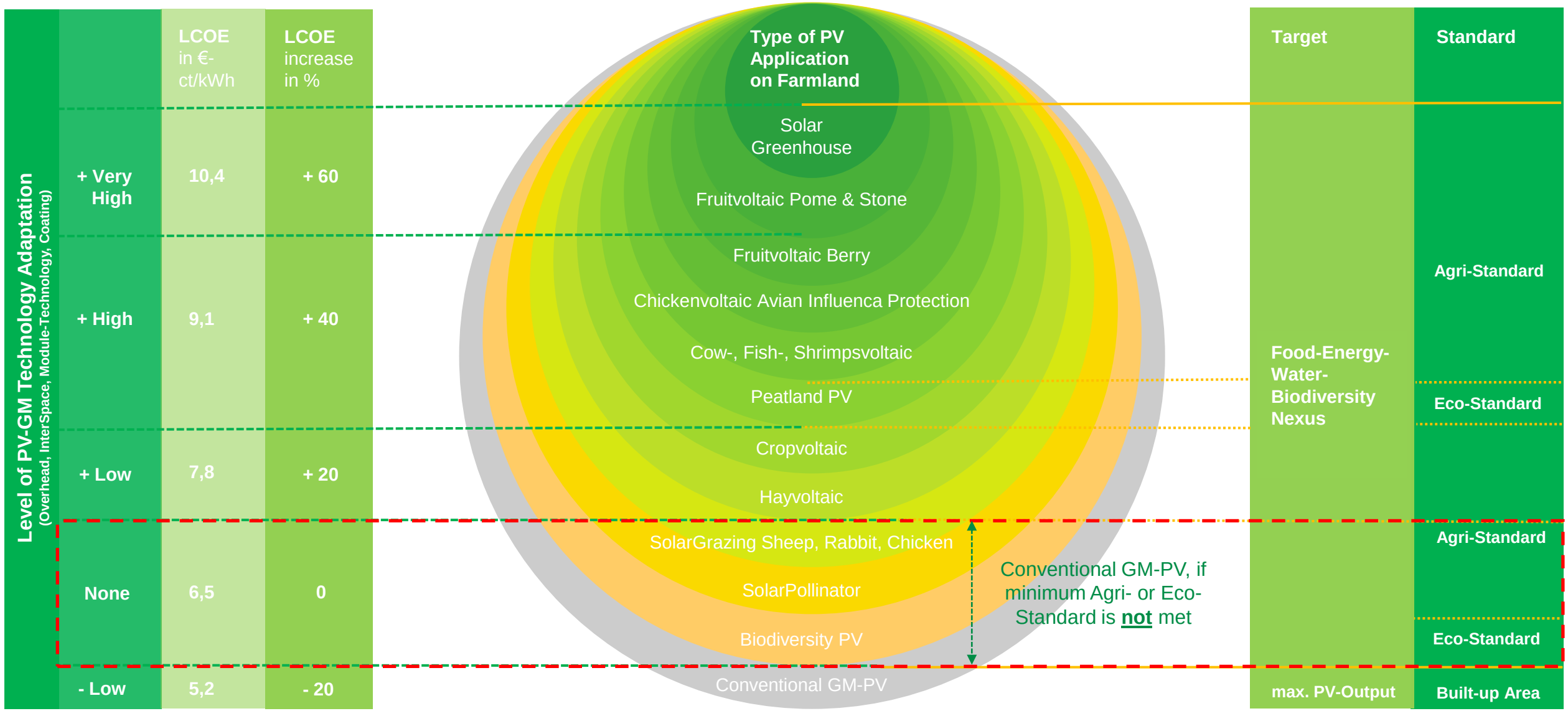
PV-Diffusion on Farmland in Harmony with Agriculture and Nature Conservation

Poly-crises demanding multi-functional land-use: energy only is not enough!

- Since 1981, the original idea of “dual harvest” from Goetzberger/Fraunhofer ISE has evolved
- Today, Agri-PV is…
  - …not “only” diminishing land-use competition → there is enough farmland available for utility-scale PV
  - …considering the Food-Energy-Water-Biodiversity Nexus
  - …integrating stakeholders into project implementation and operation → balancing interest between three sectors
  - …providing economic, ecological, and social value added on local and macro-economic level
  - …enhancing the level of sustainability in the farming and PV sector
  - …increasing the farmer’s resilience by facilitating their climate change adaptation & mitigation strategy: income diversification

- Long-term policy trend: multifunction land-use is stimulated, monofunctional land use is de-stimulated
  - Overcome silo-thinking, leverage synergies of two/three sectors, easier approval process in permitting, more funding…
  - So what is the problem? Change management, policy-learning, urgency, growing industry, priorities, complexity,…
- Reality check: is Agri-PV a business opportunity? What is the LCOE increase of Agri-PV compared to ground-mounted PV?

Overview PV Applications on Farmland & Comparative LCOE Analysis



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= Technically Ground-mounted PV, but incl. SolarGrazing, SolarPollinator, Biodiversity measurements; Legal aspects are challenge

2

Learning by Doing:
Agri-PV References by BayWa r.e.

BayWa r.e. solutions in the field of Agri-PV implementation

Agri-PV is as divers as farming sector

Agri-PV

Fruitvoltaics
Overhead

Examples:

“Berries” “Pome & Stone”

Hay- & Cropvoltaics
Interspace

Examples:

“Cereals & Vegetables & Hay”

Rangevoltaics
Overhead/Interspace

Examples:

“Animal Husbandry”

Biodiversity-PV
Interspace

Examples:

“Pollinator”

SolarGreenhouse
Controlled Atmosphere

Examples:

“Nursery & Herbs”

Main Challenges in Agri-PV Project Development

- **Capacity building:** establish the “Varieties of Agri-PV” in all functions, e.g. PD, EPC, PM, Legal, MKTG, MGMT, Sales, …
- **Stakeholder engagement:** cross-sector collaboration demands coordination, e.g. farming, environment, permitting, policy,…
- **Quality assurance:** capacity building in PD, process standardization & optimization, lessons learned, knowledge mgmt., …
- **Business & market intelligence:** knowledge transfer to countries, new organization structures, tech-adaptation, strategy,…

Learning by Doing: 13x Fruitvoltaics, 2x Cropvoltaics, 1x SolarGreenhouse / end of 2023
10x in the Netherlands & 3x in Germany & 2x in Austria & 1x in Spain


Heggelbach (GER), 2016


Babberich I (NL), 2019


Babberich II (NL), 2020


Wadenoijen I (NL), 2020


Broekhuizen I (NL), 2020


Boekel I (NL), 2020


Schootsedijk I (NL), 2020


Wadenoijen II (NL), 2021


Pöchlarn (A), 2021


Gelsdorf (GER), 2021


Haidegg (A), 2022


Randwijk (NL), 2022

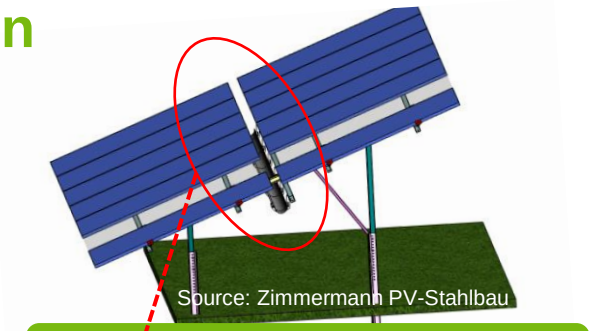
Learning by Doing: 13x Fruitvoltaics, 2x Cropvoltaics, 1x SolarGreenhouse / End of 2023

10x in the Netherlands & 3x in Germany & 2x in Austria & 1x in Spain

Enspijk (NL), 2022

Weinsberg (GER), 2022

Medemblik (NL), 2022



Alhendin (ES), 2023

- **9x Fruitvoltaics Berries:** Raspberry, Strawberry, Blackberry, Blueberry, Red Currant
- **4x Fruitvoltaics Pome & Stone Fruite:** Apple, Pear, Cheery, Plum
- **2x Interspace/Cropvoltaics**
- **1x SolarGreenhouse**

Water-Harvesting with PV-modules
Food-Energy-Water-Biodiversity Nexus

- **2x Cross-Segment**
  - Power Solution for RWA: PJ Pöchlarn (A)
  - Solar Distribution for LVWO Weinsberg: PJ Weinsberg (D)
- **2x EPC 3rd Party Sales:** We offer our Agri-PV solutions Turn-key Ready to 3rd Party Customers in Farming & Energy Sector

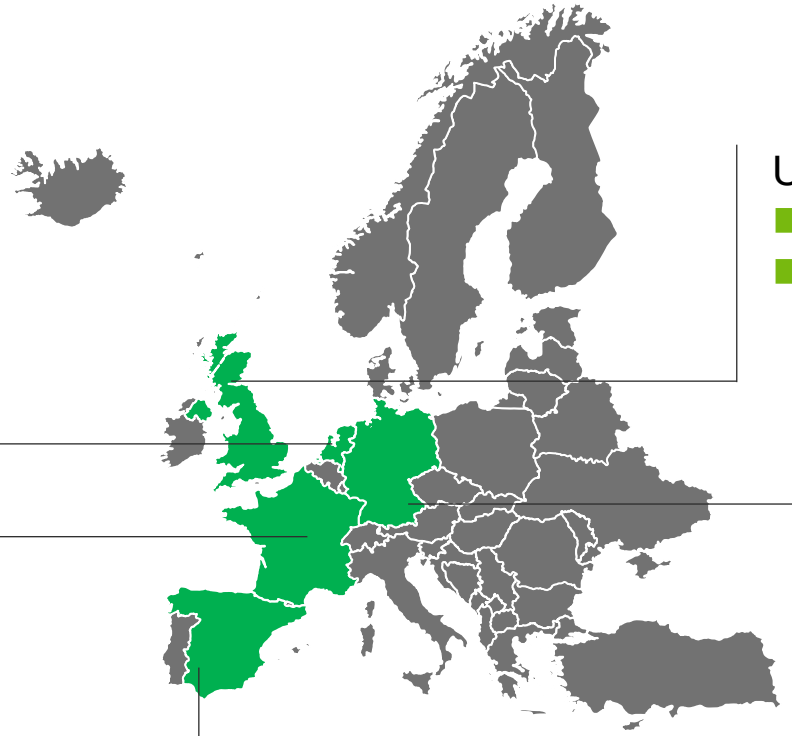
41 MWp of Fruitvoltaics, SolarGreenhouse, Cropvoltaics

Learning by Doing: 34x SolarGrazing with Sheep Projects in Europe / End of 2023

7x in France & 4x in the Netherlands & 8x in Germany & 10x in UK & 5x in Spain

France
- 125 MWp
- 198 ha

Netherlands
- 108 MWp
- 112 ha



UK
- 228 MWp
- 358 ha

Germany
- 54 MWp
- 66 ha

Spain
- 470 MWp
- 693 ha

985 MWp of Solar Grazing installed in Europe on an area of 1,516 hectares


Project Exloo (NL)


Project Barth (D)


Project Tordesillas (ES)


Project Seifertshofen (D)

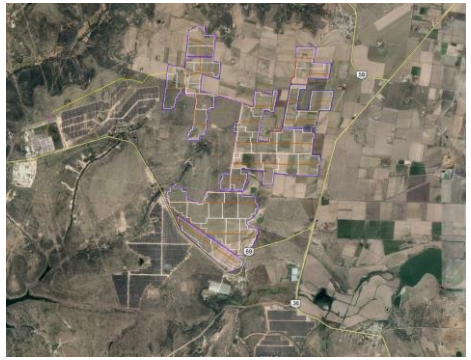

Project Forest Heath (UK)


Project Fontenet (FR)

Learning by Doing: 2x Biodiversity-PV/SolarPollinator / End of 2023
1x in Mexico & 1x in Germany

Example Mexico

Stakeholder inclusion: Health, Safety & Environmental Regulations, Social & Legal Adaptation of PV-Project



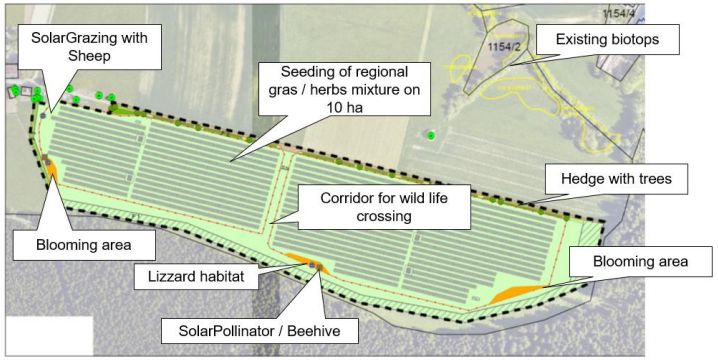


- 200 MWp installed PV capacity
- 400 beehives installed within project area
- 20 families operating beehives (approx. 20 beehives/family)
- 48 Kg of honey/beehive/year = 960 Kg/year/family
- 19.200 Kg of honey/year on project area
- Additionally 71 hectares of reforestation next to project including 5 native species attracting pollinators

Learning by Doing: 2x Biodiversity-PV/SolarPollinator / End of 2023
1x in Mexico & 1x in Germany

Example Germany:

Stakeholder inclusion: project development together with local Nature and Biodiversity Conservation Union (NABU)



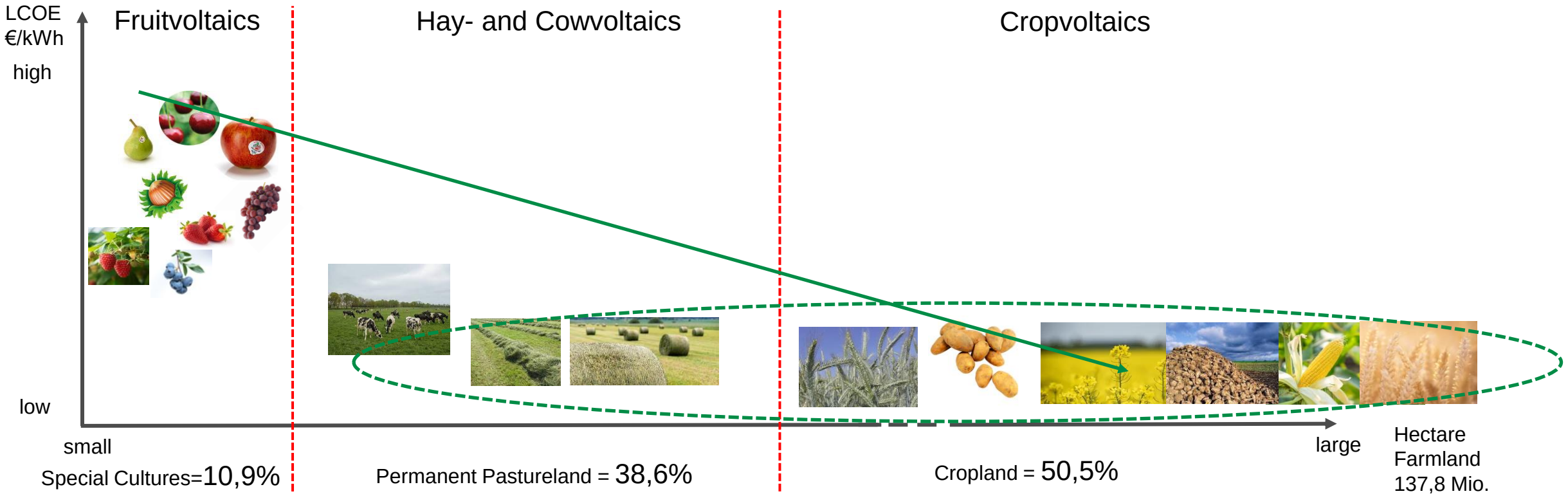
- 9 MWp PV and 4 MWh BES
- BioDiv-Quality of set a site area vs. BioDiv-PV (not Agri before vs. BioDiv-PV)
- Goal of family owning the farmland: restore damaged ecosystem, increase biodiversity, climate protection
- 10x biodiversity measurements integrated into solar park together with local environmentalist group NABU
  - Blooming area
  - Lizard habitat
  - Regional seeding
  - SolarPollinator / Beehives
  - SolarGrazing with Sheep
  - Hedges with local trees
  - Corridor for wild life crossing
  - Soil degradation neutrality
  - Bird housing
  - Upgrade of existing biotops

3

The Future (of Utility-scale PV) is Agri-PV

Agri-PV Area Potential in EU: Special Cultures, Permanent Pastureland, Cropland

Relation LCOE to Area Potential

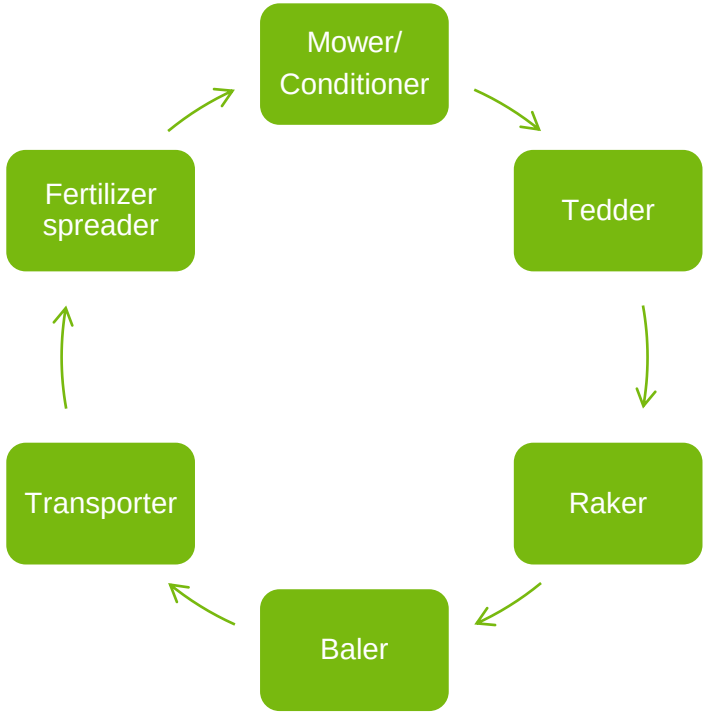


Conclusion:

- Great business opportunity for low LCOE, large area potential: Cropvoltaics, Hayvoltaics, SolarGrazing, Biodiversity-PV
- Fruitvoltaics, Cowvoltaics, and SolarGreenhouse business opportunity only, if financial support mechanism is in place
- BUT: we/solar sector must have the motivation to learn & find comprise with farming sector and vice versa: expl. **Hayvoltaics**

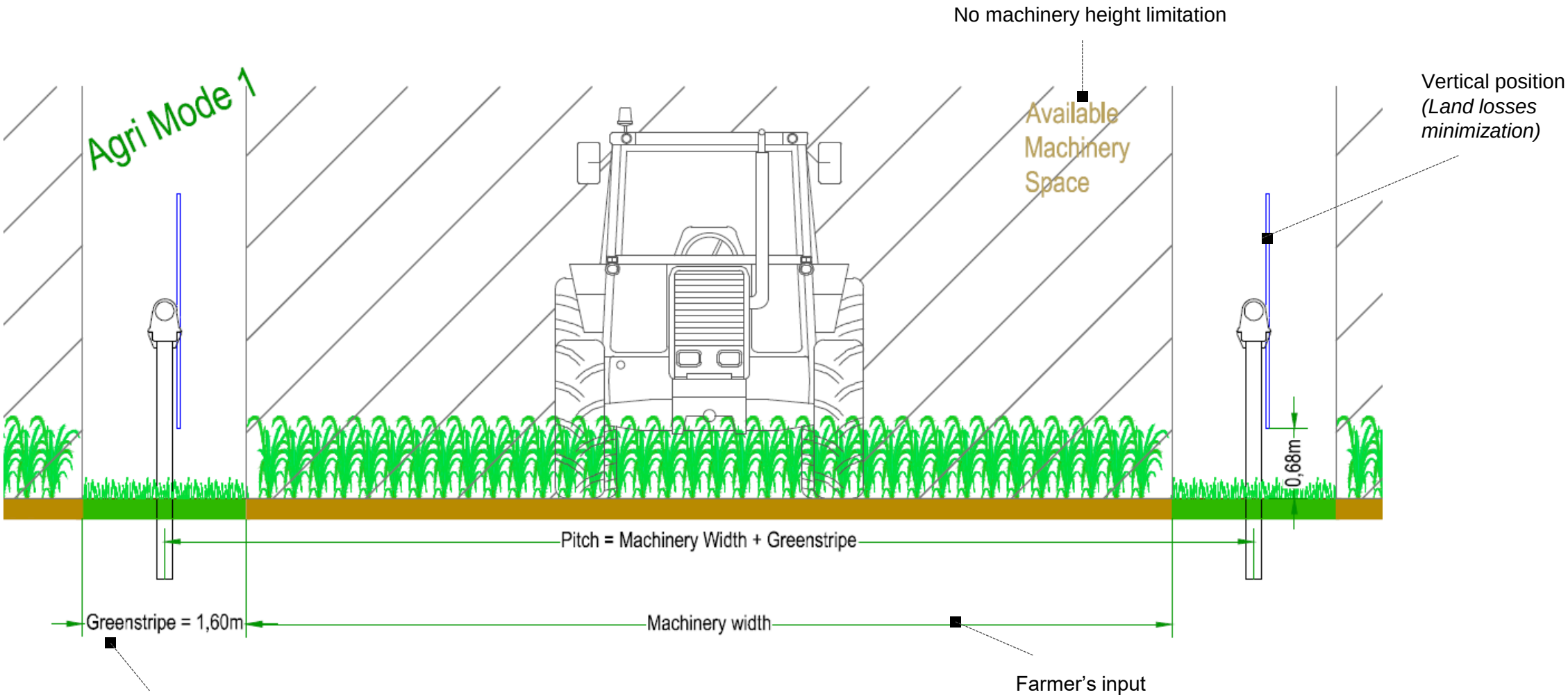
Typical machineries

Example: Hay production



Configurations: Operational Guidelines

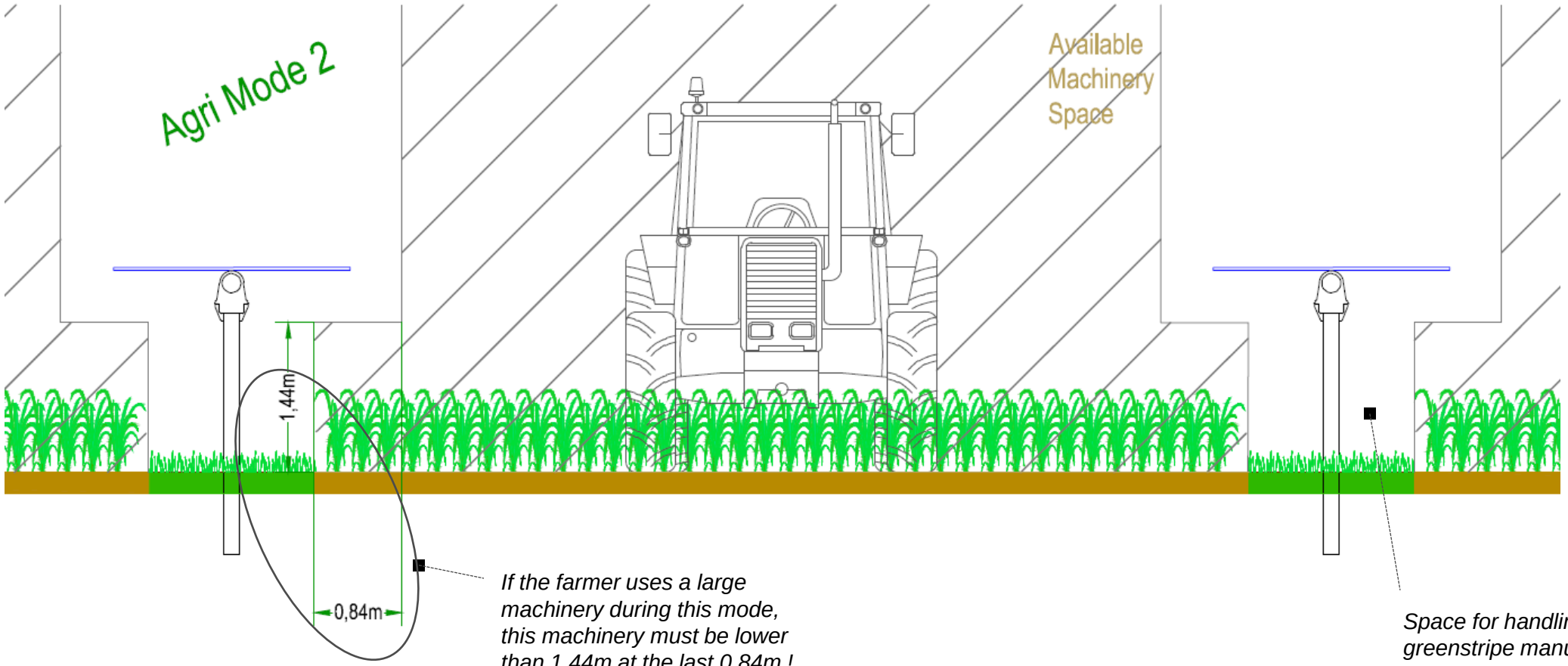
Tracking 1P: Agri Mode 1



In case of GPS driving greenstripe = 1,6m (assuring 0,5m safety distance on both sides and 0,6m occupied by the tracker width)
In case of non-GPS driving the greenstripe is 2,6m (1,0m safety distance)

Configurations: Operational Guidelines

Tracking 1P: Agri Mode 2



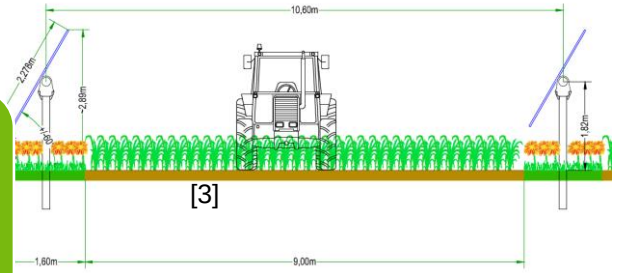
If the farmer uses a large machinery during this mode, this machinery must be lower than 1,44m at the last 0,84m !

Space for handling of the greenstripe manually or with small size machineries (e.g. robotic mowers)

Quality Assurance: Agri-PV 5C-Tool

Process Optimization in Project Development

1)
Conditions:
Crop type, microclimate, machineries, soil, irrigation, farming practise



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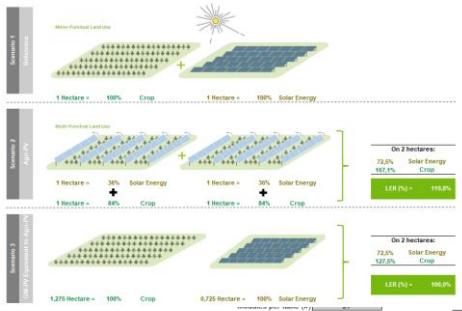
2)
Configurations:
Pitch, Height, Azimuth

5)
Collaboration:
Legal Framework, HSE, O&M, Authorities, Research, Press, Media

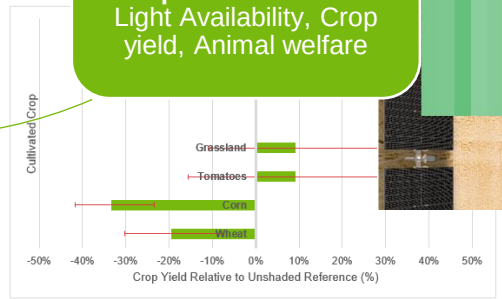


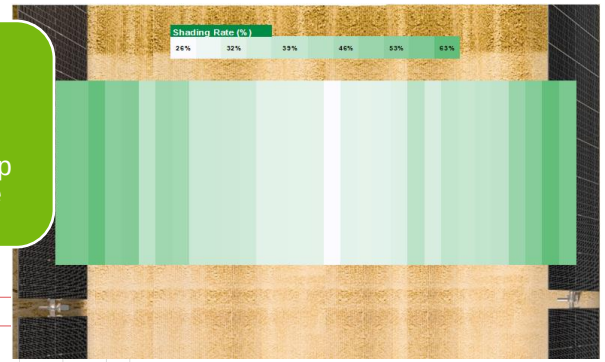
Item	Quantity				
Module tables	684	30,0			
Container (storage - 20 feet)	1	6,1			
Container (battery - 40 feet)	1	12,2	2,4	29,7	30
Transformer station building (630-1800kVA)	1	3,4	2,2	7,3	7
Transformer station building (2500-3150kVA)	16	4,1	2,9	11,8	188
				Total Component Area:	12.806

Green area in front of the module tables	1	20.942,7	0,5	10.471,4	10.471
Green area behind of the module tables	1	20.942,7	0,5	10.471,4	10.471
Green are in front of the fence	1	3.413,0	0,5	1.706,5	1.707
Green area in front of the system periphery	305	0,6	1,0	0,6	183
Green area on the O&M roads	2	700,0	5,0	3.500,0	7.000
Green are in front of the containers	1	46,3	0,5	23,1	23
Green are in front of the transformer stations	1	234,1	0,5	117,1	117
				Total Green Area:	29.972

Agriculturally available land (m2)	307.222
Agriculturally unavailable land (m2)	42.778
Land Losses (%)	12,2%

4)
Compatibility:
Land Losses & LER Calculation, National Standards





3)
Crop & Animal performance:
Light Availability, Crop yield, Animal welfare

Summary

- Energy only is not enough!
- Agri-PV is very divers: setting the right priorities
- Farming and PV business is kept separately: two independent business cases on one area
- Capacity learning and knowledge management needs coordination: process optimization 5C-Tool
- Agri-PV solutions with low LCOE: subsidy free
- Agri-PV solutions with higher LCOE: need funding
- Many governments stimulate multifunctional land-use
- Agri-PV diffusion is only at the introduction phase, growth phase is starting in years 2025 – 2030

Thank you

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Techno-Economic Analysis of Rangevoltaics

Data (Part 1/2)

Project size: 20 MWp; Location: Central France

	PV-GM Tracker (>20 MW)		SolarGrazing or SolarPollinator fixed-tilt (>20 MWp)		Cowvoltaics overhead Tracker (>20 MW)	
	Minimal assumption	Maximum	Minimal assumption	Maximum	Minimal assumption	Maximum
CAPEX (EUR/kWp)	800	1100	750	1000	975	1400
Interest rate (%)	5,00%	5,00%	5,00%	5,00%	5,00%	5,00%
Operating time (a)	25	25	25	25	25	25
OPEX (EUR/kWp/a)	12	16	11	15	13	18
Orientation	East-West		South		East-West	
kWh/kWp/a	1750	1150	1600	950	1750	1150
Capital costs per year (EUR/kWp/a)	57	78	53	71	69	99
LCOE (ct/kWh)	**3,93**	**8,18**	**4,01**	**9,05**	**4,70**	**10,20**

- Cowvoltaics tracker is higher than standard tracker and cabling more secure → higher CAPEX, but same power yield

Techno-Economic Analysis of Rangevoltaics

Data (Part 2/2)

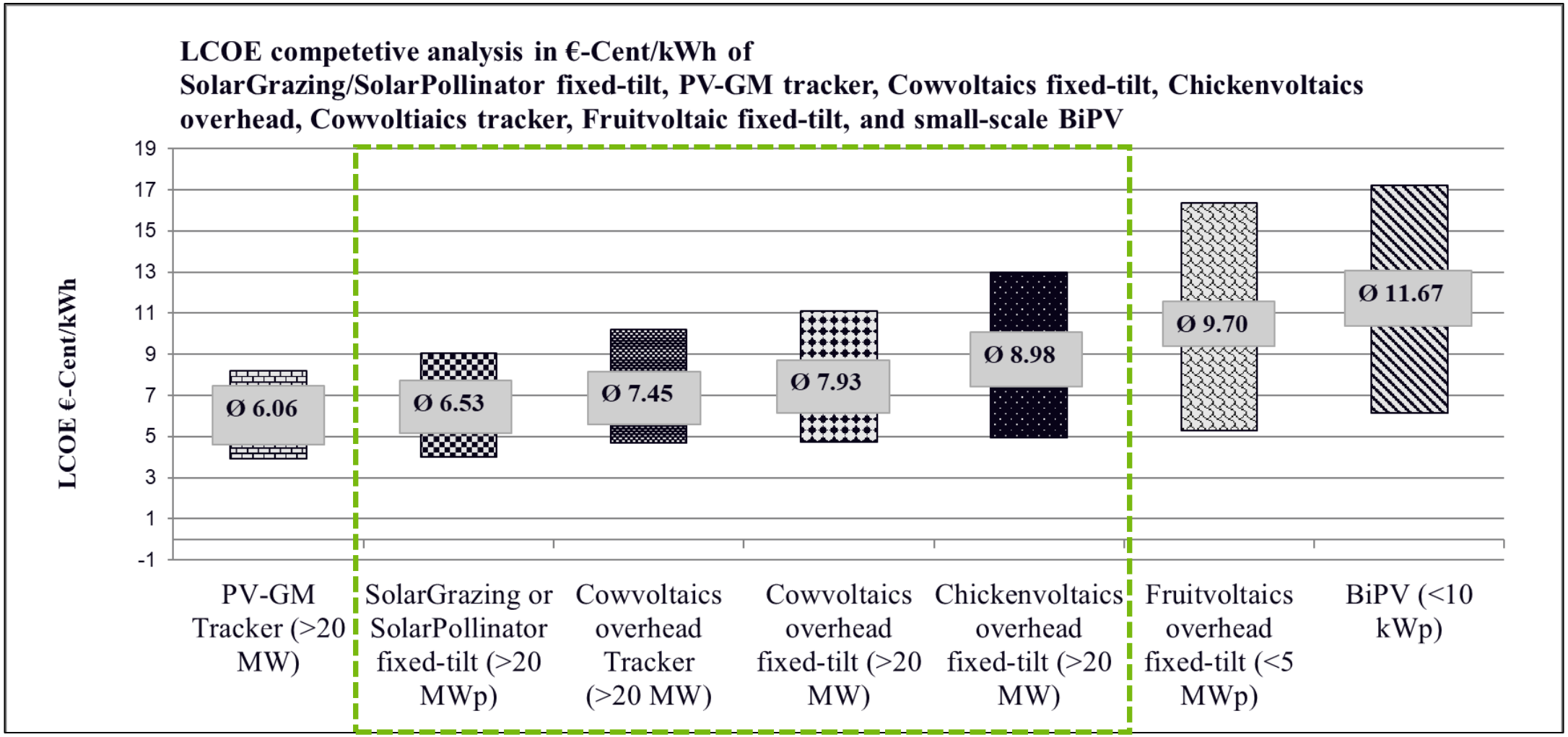
Project size: 20 MWp; Location: Central France

	Cowvoltaics overhead fixed-tilt (>20 MW)		Chickenvoltaics overhead fixed-tilt (>20 MW)		Fruitvoltaics overhead fixed-tilt (<5 MWp)		BiPV (<10 kWp)	
	Minimal assumption	Maximum	Minimal assumption	Maximum	Minimal assumption	Maximum	Minimal assumption	Maximum
CAPEX (EUR/kWp)	900	1250	950	1500	1000	1550	1100	1750
Interest rate (%)	5,00%	5,00%	5,00%	5,00%	5,00%	5,00%	6,00%	6,00%
Operating time (a)	25	25	25	25	25	25	25	25
OPEX (EUR/kWp/a)	12	17	12	17	11	17	12	18
Orientation	South		South		East-West		South	
kWh/kWp/a	1600	950	1600	950	1550	900	1600	900
Capital costs per year (EUR/kWp/a)	64	89	67	106	71	110	86	137
LCOE (ct/kWh)	**4,74**	**11,13**	**4,96**	**12,99**	**5,29**	**14,11**	**6,13**	**17,21**

- Compared to Fruitvoltaics, Rangevoltaics has lower LCOE, & larger area potential: positive cost-benefit ratio for policy makers
  - Higher CAPEX (due to light transmitting PV module), but lower PV yield (due to east-west conficuration)
- Integrating-PV on roof-tops and buildings (top-priority in many markets) is more costly than Agri-PV/Rangevoltaics

Techno-Economic Analysis

Results



Rangevoltaics