Experiences from vertical bifacial agrivoltaic projects on grassland

Jerome Lintz ▪ 19 November 2025 ▪ j.lintz@next2sun.de ▪ www.next2sun.com

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We stand for energy transition.

Agenda

- Introduction to Next2Sun & Vertical Bifacial PV
- Presentation of Project Example
- Presentation of Selected Collected Data
  - Energy Production/Market Value
  - LCOE
  - Agricultural Yields
- Conclusion

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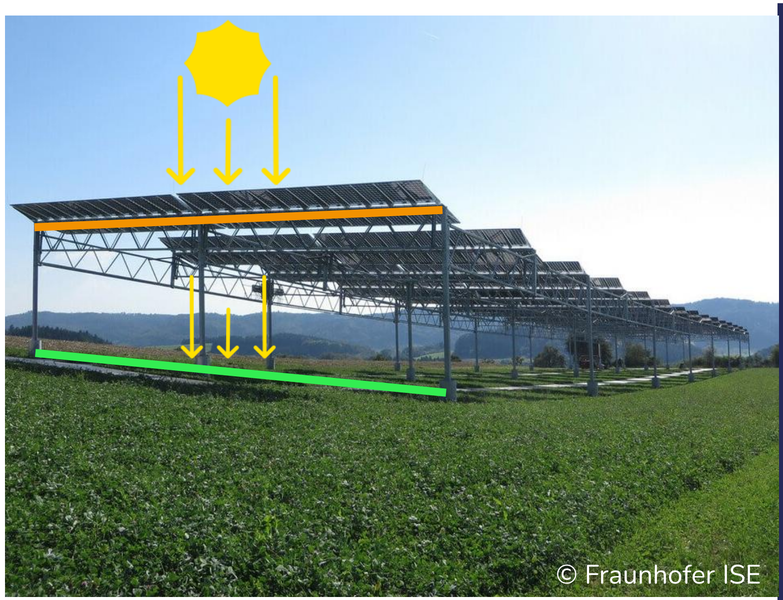
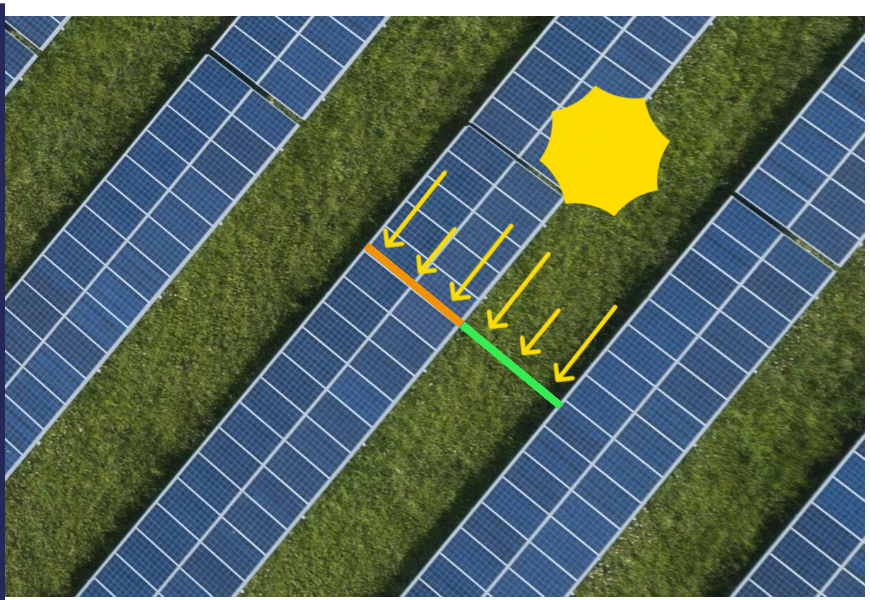
Next2Sun is the inventor and technology leader in the field of vertically installed, bifacial photovoltaics.

- Founded in Germany in 2015
- > 60 MWp projects realised
- > 140 employees
- Locations in Germany, Austria, Poland and Japan

Different types of agrivoltaics in the market





High elevated

⬇

Double land use

on two levels

Vertical bifacial

⬇

Double land use in different dimensions

(PV: vertical ⇔ Agriculture: horizontal)

Other ground mounted concepts

⬇

Land use side by side

Agricultural use often limited

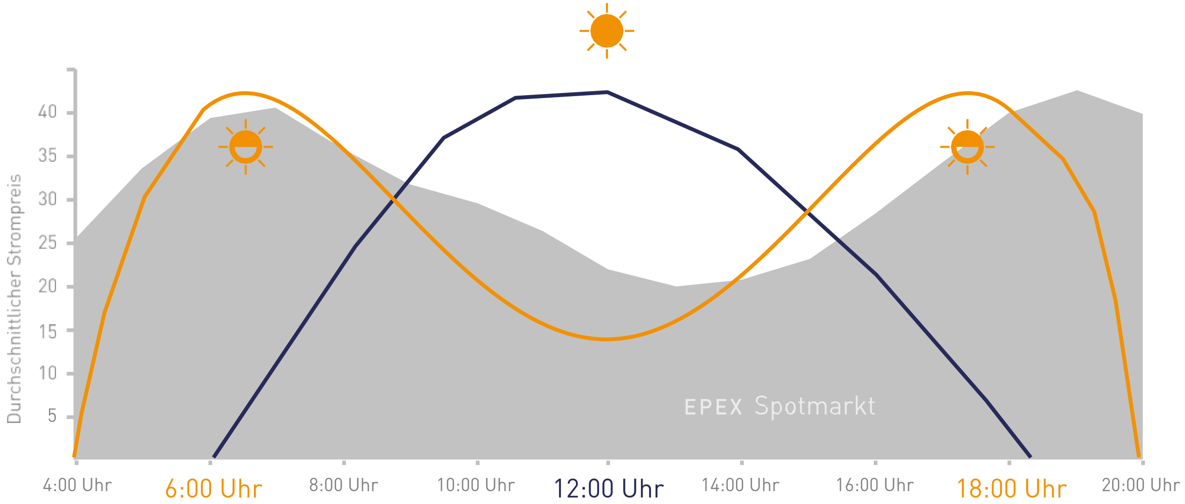
SYNERGY

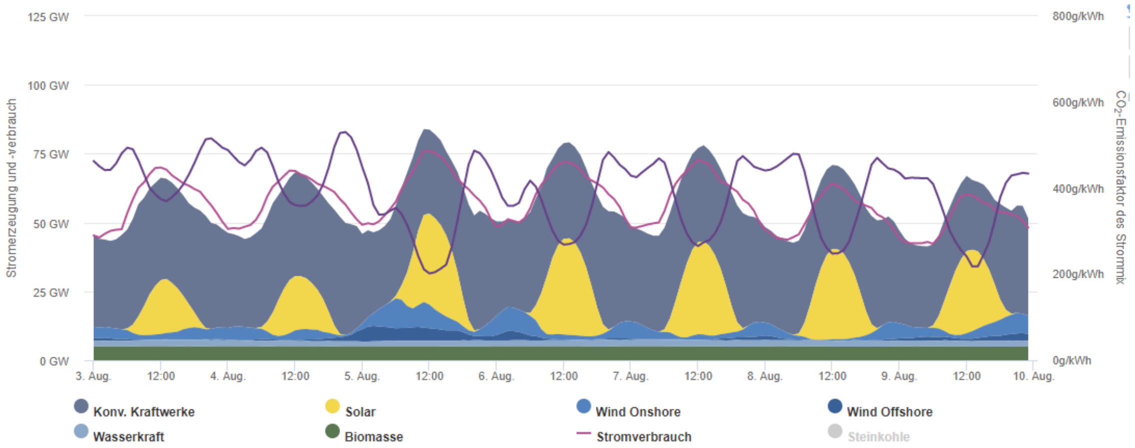
Advantages of vertical bifacial agrivoltaics

Dual land use works!

- ✓ PV Installation covers less than 1% of the plant
  - → Unchanged water supply
  - → Only small change in solar radiation (10-15% of annual energy)
- ✓ App. 90% of the land can be cultivated with conventional agricultural machinery
- ✓ Positive impact on vegetation and crop yield possible

Vertical bifacial Next2Sun systems produce electricity when needed





PV systems with east-west orientation consistently thought to the end:

- The modules surfaces are aligned **vertically** to the east and west
- By using **bifacial** (light-sensitive) solar modules on both sides, both sides can generate power with a single solar module

→ **Electricity production primarily in the morning and evening hours!**

Higher yield

Higher market value

10 - 25 % Additional proceeds

Presentation of Project Example

Agri-PV Eppelborn-Dirmingen, Saarland

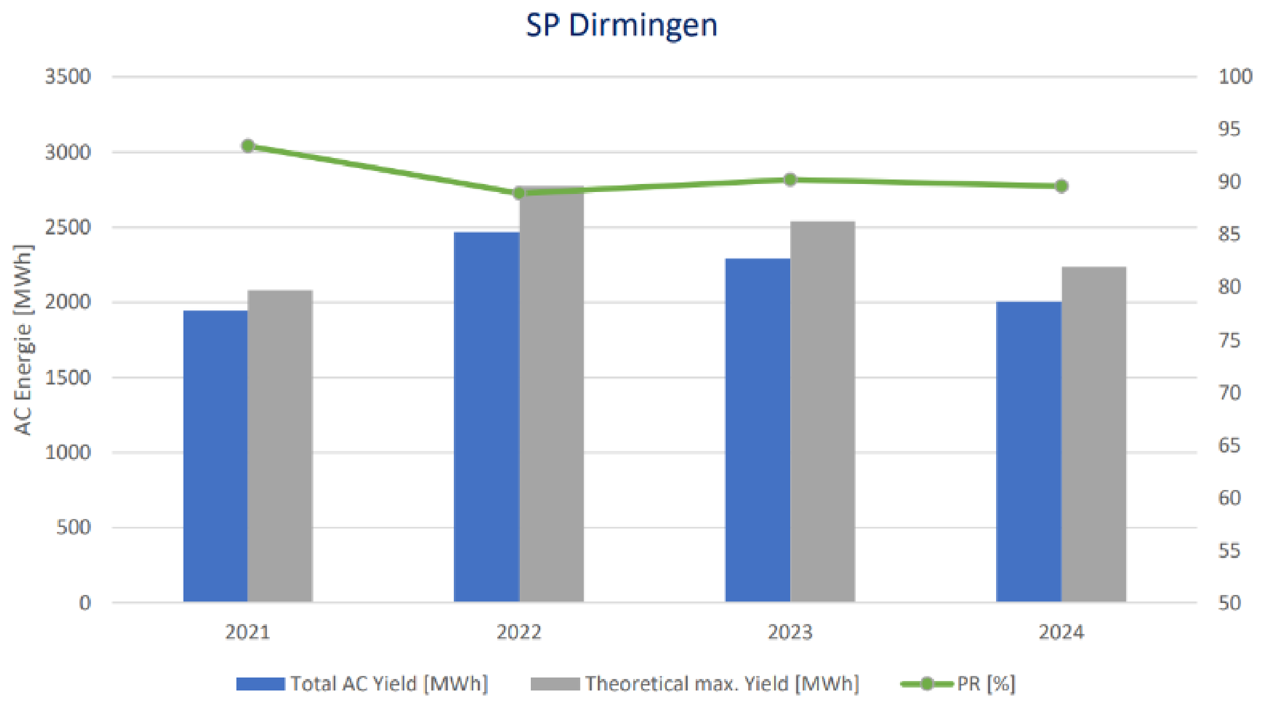
Brief Description	The Agri-PV system in the Eppelborn district of Dirmingen is Next2Sun's first large-scale vertical bifacial system worldwide and also provided the technical proof of concept for the Next2Sun system. The system was commissioned in 2018 on a module field area of around 7 hectares and has been supplying around 700 households with renewable electricity ever since. In addition to hay production, the 10-meter-wide row spacings are also used for silage production.
Commissioning	2018
Annual energy yield	2.150 MWh/year
Installed capacity	2 MWp
Orientation	Vertically east-west
Technology	N-Pert (60%), Heterojunction (40%)
Agricultural Use	Hay, Silage
Power usage	Grid feed-in according to EEG
Other	Europe's first vertical bifacial agri-photovoltaic system

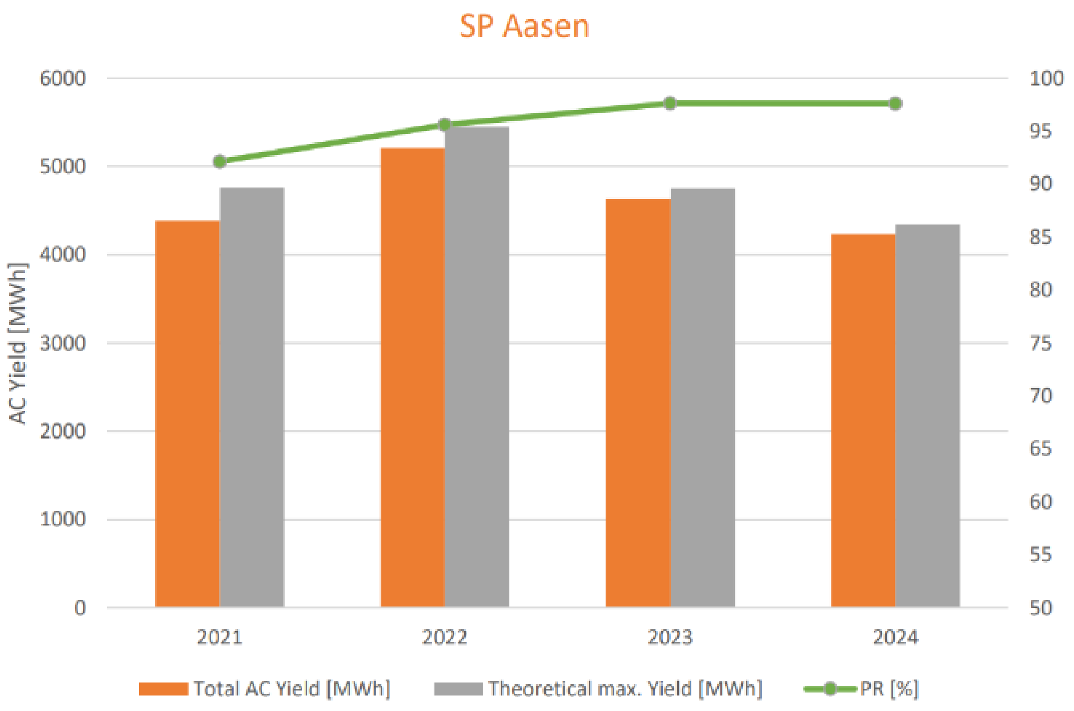
Presentation of Project Example

Agri-PV Donaueschingen-Aasen, Baden-Württemberg

Brief Description	In July 2020, Europe's largest vertical, bifacial Agri-PV system was built in the Donaueschingen district of Aasen. A total of 11,000 bifacial solar modules were installed on a module field area of around 12 hectares. The agricultural follow-up use will be carried out by the previous farmer. The 10-meter-wide spaces between the rows will continue to be used for the production of hay and silage. In addition, three further rows of modules will be used for agricultural cultivation trials. The agri-PV system supplies 1,400 households with renewable electricity.
Commissioning	2020
Annual energy yield	4.850 MWh/year
Installed capacity	4.1 MWp
Orientation	Vertically east-west
Technology	N-Pert
Agricultural Use	Hay, Silage, Field Pea
Power usage	Grid feed-in according to EEG
Other	Europe’s largest vertical bifacial agri-photovoltaic system

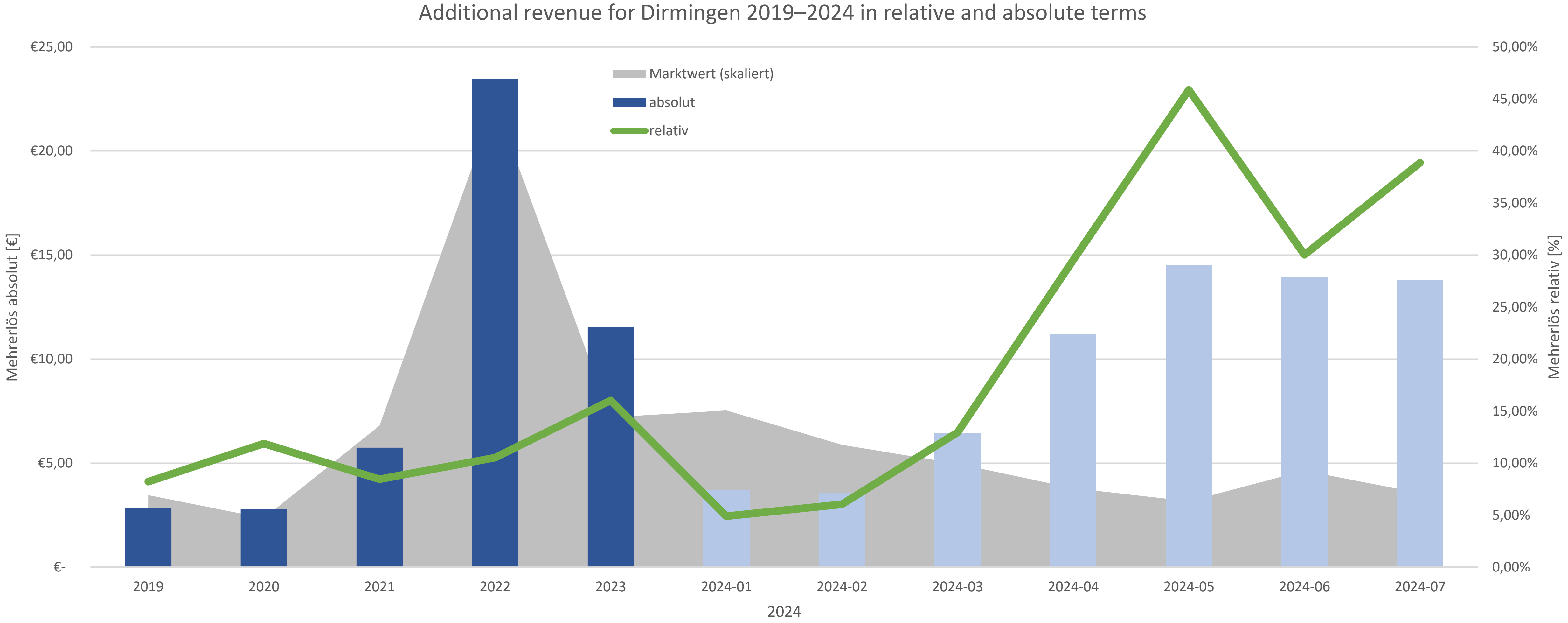
Performance of the systems in relation to the measured solar radiation energy





*Theoretical max. yield = Idealized forecast based on measured irradiation values, assuming 100% system efficiency

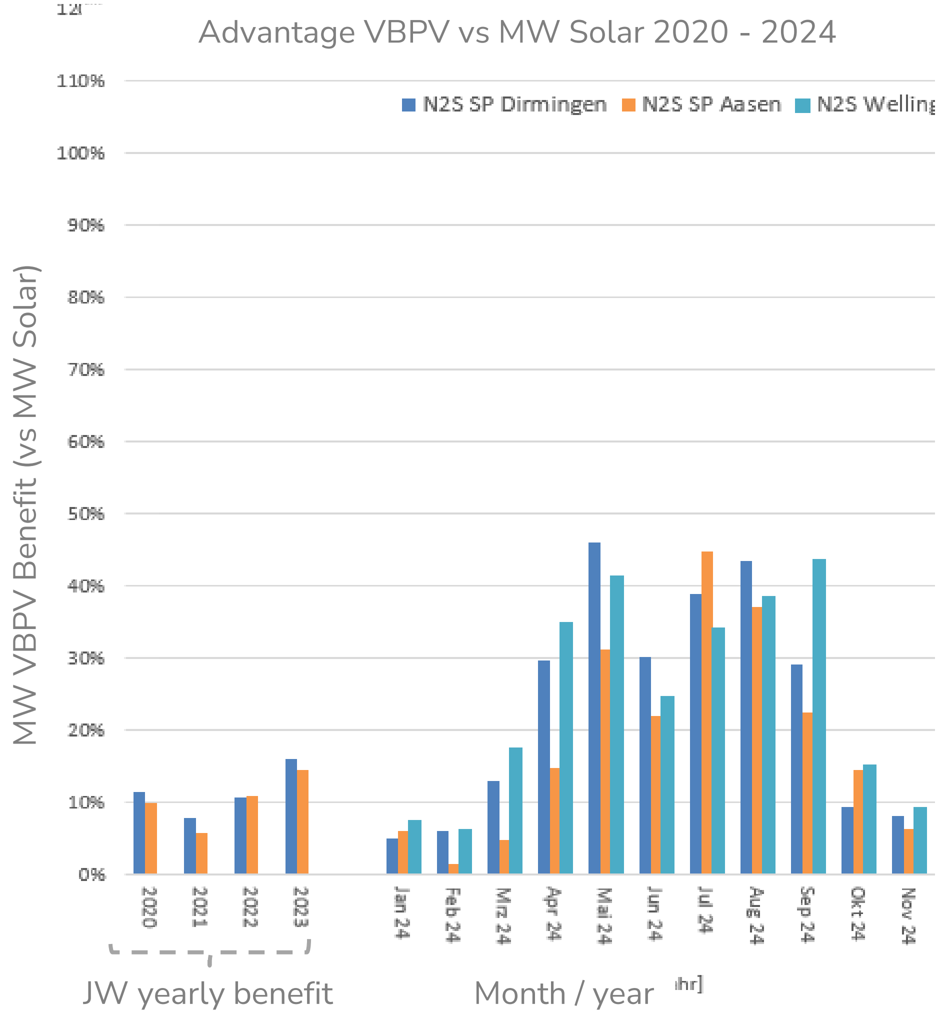
Market value of vertical bifacial PV rises steadily compared to market value of solar panels in 2024



Sources: 2024, Szabo et al., **Impacts of large-scale deployment of vertical bifacial photovoltaics on European electricity market dynamics**

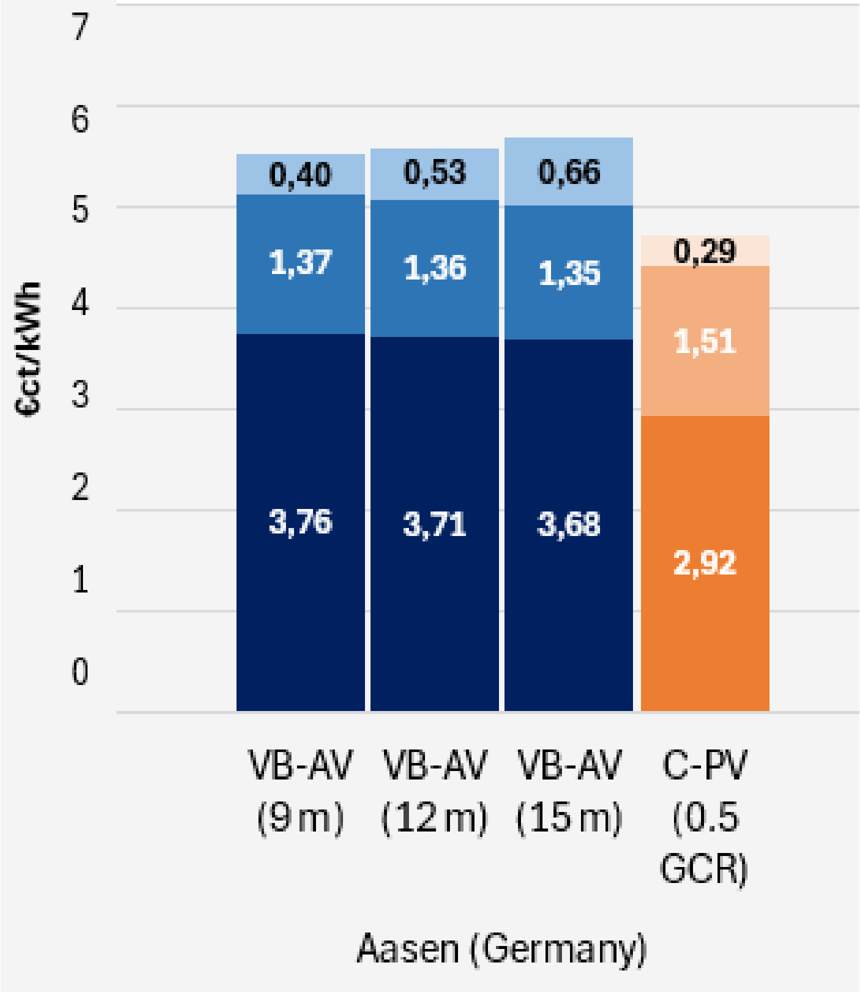
Historical market value of VBPV to MW Solar Germany

Monthly market value difference in percent [%]: **Dirmingen**, **Aasen**, and **Wellingen** from August 2020 to present



- Comparing VBPV and MW Solar Germany from 2020 to 2025: Continuous Growth
- Yearly profile-value JW in 2024: Dirmingen +27% (+12,74 €/MWh), Aasen +25% (+11,80 €/MWh), Wellingen +28% (+12,87 €/MWh)
- **Demand-oriented energy production results in rising profitability**

LCOE (Aasen)



Assumptions

- Lifetime: 25 Years
- Discount rate 5 %
- Degradation VB-AV: 0.3 % [2]
- Degradation C-PV: 0.44% [4]

Findings

- Optimized module degradation in VB-AV contributes to improved LCOE. [4]

While CAPEX optimizations have reduced the LCOE gap between VB-AV and C-PV, higher variable OPEX - driven by land lease costs due to lower specific installed capacity - remain a key economic drawback.

Economics efficiency of Next2Sun systems already proven, further learning and economies of scale expected

Revenues

•Sales	4 tsd € kW	*	1.150 kWh/kW	* 0,06€/kWh	= 276 tsd. €

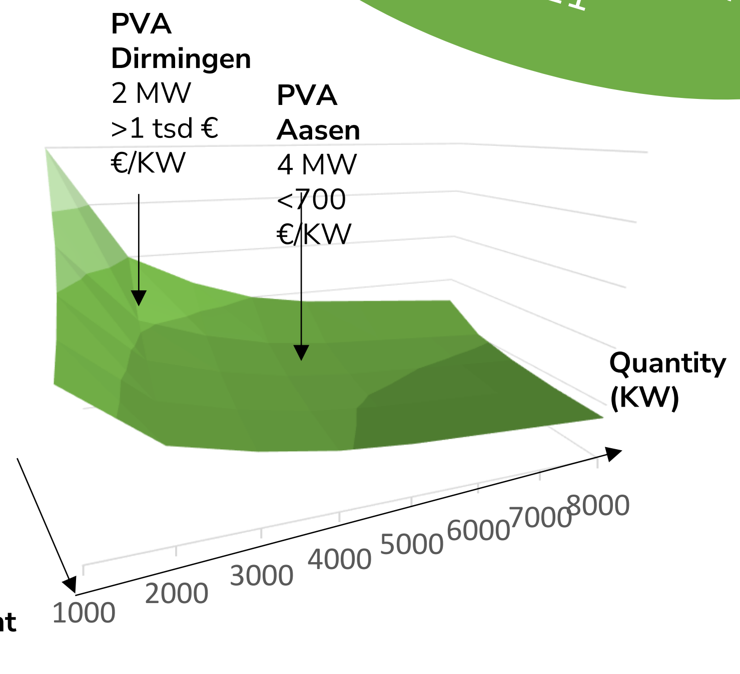
- Costs

•Lease & land maintence	17 ha	*	-1 tsd €€/ha	= -25,5 tsd. €
•Technical operation	4.00 kW	*	-8,5€/kW p.a.	= -34 tsd. €
•Marketing	4.400 MWh	*	-0,8€/MWh	= -3,5 tsd. €
•Administration	1 Entity (LE)	*	-9 tsd €€/LE p.a.	= -9 tsd. €
•Depreciation	2.800 tsd. €	*	-5% p.a.	= -140 tsd. €

= economies

•EBIT	= 64 tsd. €
•Internal rate of return	= 3,0 %

Cost reduction >10% already achieved for 2021



Agricultural yields

Presentation of Collected Data

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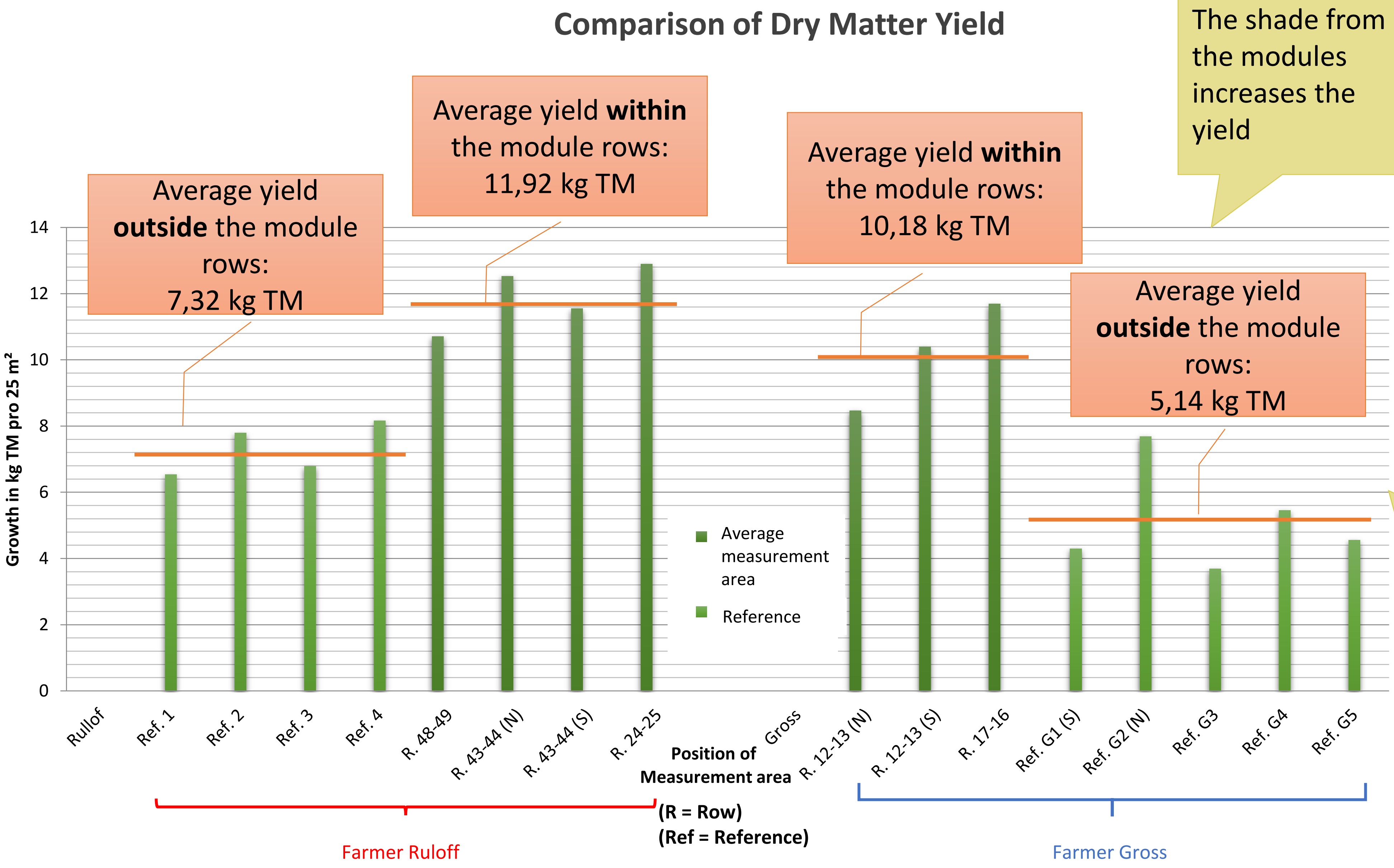
Hay Harvest 2020



Finding:

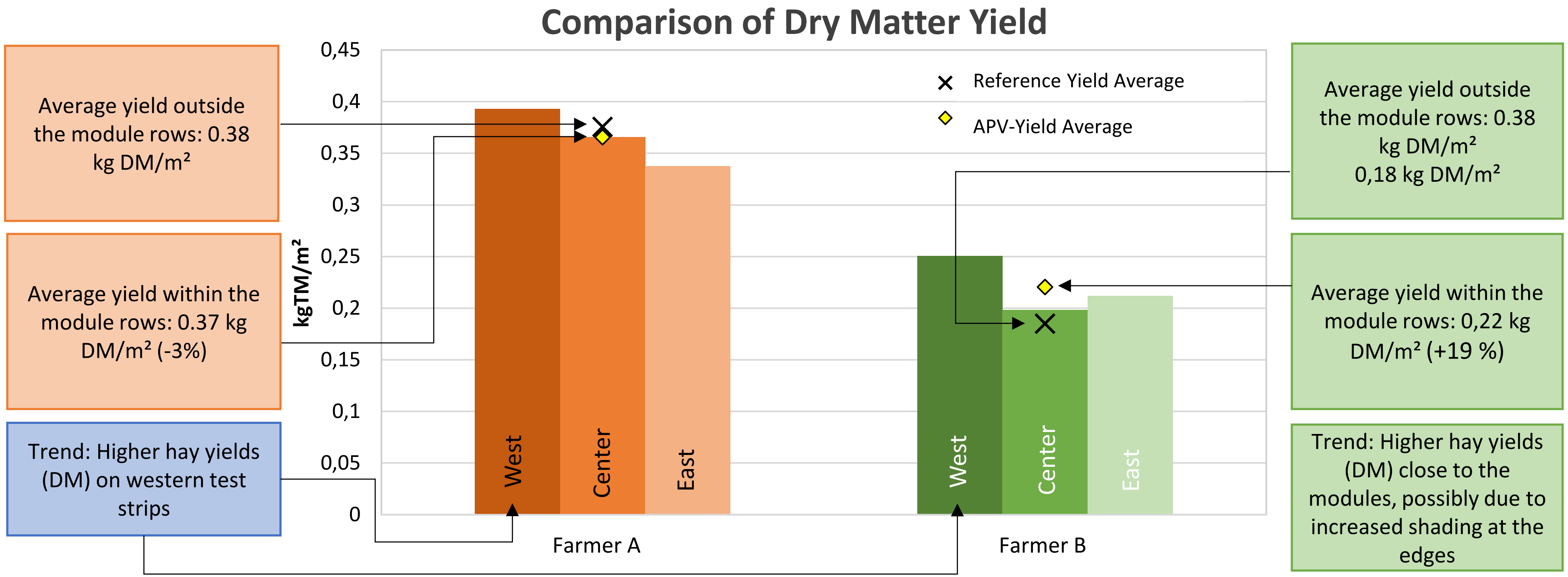
The shade from the modules increases the yield

Our results:

- Every measurement point within the module rows is better than every measurement point outside
- Minimum yield increase within the module rows: +10%
- Average yield increase within the module rows: +77%

Agricultural yields

Hay Harvest 2022



Findings:

- Yield per square meter on still suitable total land for agricultural use within the rows (90%) is approximately 108% of the yield per square meter outside the system.

→ Increase in specific yield (kg dry matter/square meter of still usable land) within the system compared to outside the system is 8%.

- Yield taking into account area losses for module racks and biodiversity strips (10%) is 99% of the yield without the APV system.

→ No significant absolute yield loss on the total area in 2022 despite 10% “area losses” due to biodiversity strips.

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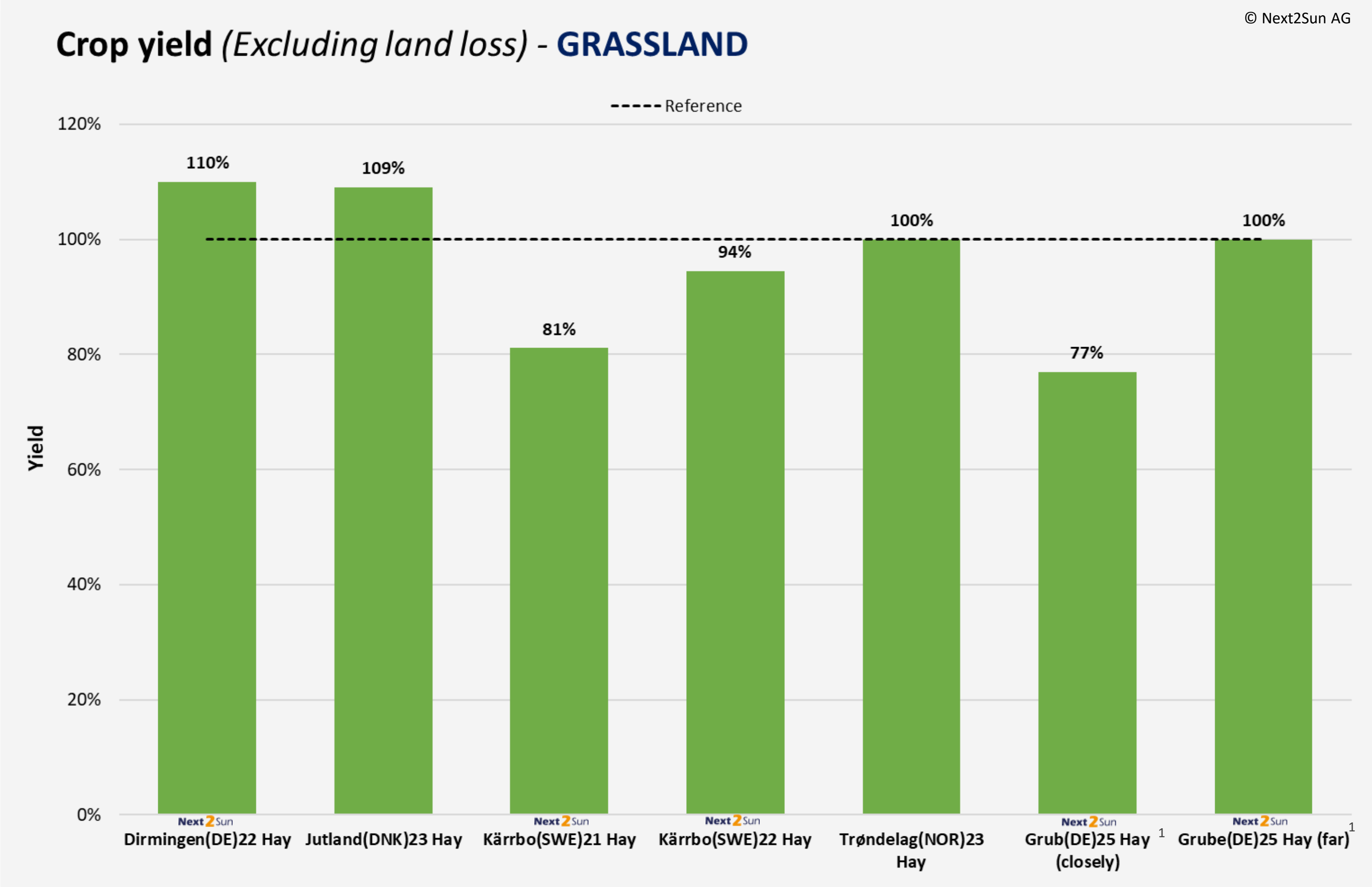
Agricultural yields

Grassland inside vs. outside vertical agri-PV



Findings

- **Average**: 96 %
- Grassland shows **steady growth**
- **Dry years** generally with **constant yields** or **increased yields**.
  - Higher probability in the future
- **Rainy years** generally with **lower yields** compared to reference area
  - Lower probability in the future
- Since the results from Grub originate from the first year after construction, an influence from construction-related soil compaction cannot be ruled out.

[1] 'closely' (14 m) and 'far' (25 m) denote the row spacing configuration of the system.

Conclusion

Findings:

- Variable OPEX remain a key challenge for VB-AV due to low power density that leaves sufficient space for agricultural use
- LCOE can underestimate the economic performance of certain systems
- Market value considerations can enhance the profitability of VB-AV
- VB-AV allows agricultural cultivation, produces energy when demanded → grid-friendly energy supply
- Several successful VB-AV projects provide practical evidence of potential

Practical Implementations:

- VB-AV and its benefits are in the regulatory framework often neglected what complicates expansion → regulatory uncertainties

→ Need for a regulatory framework that acknowledges potential of VB and incentivizes expansion

→ Need for an APV regulation that prevents “Pseudo-APV”- projects that don’t leave room for agricultural cultivation but focus on the PV-side and exploit APV privileges

Thank you for your attention.

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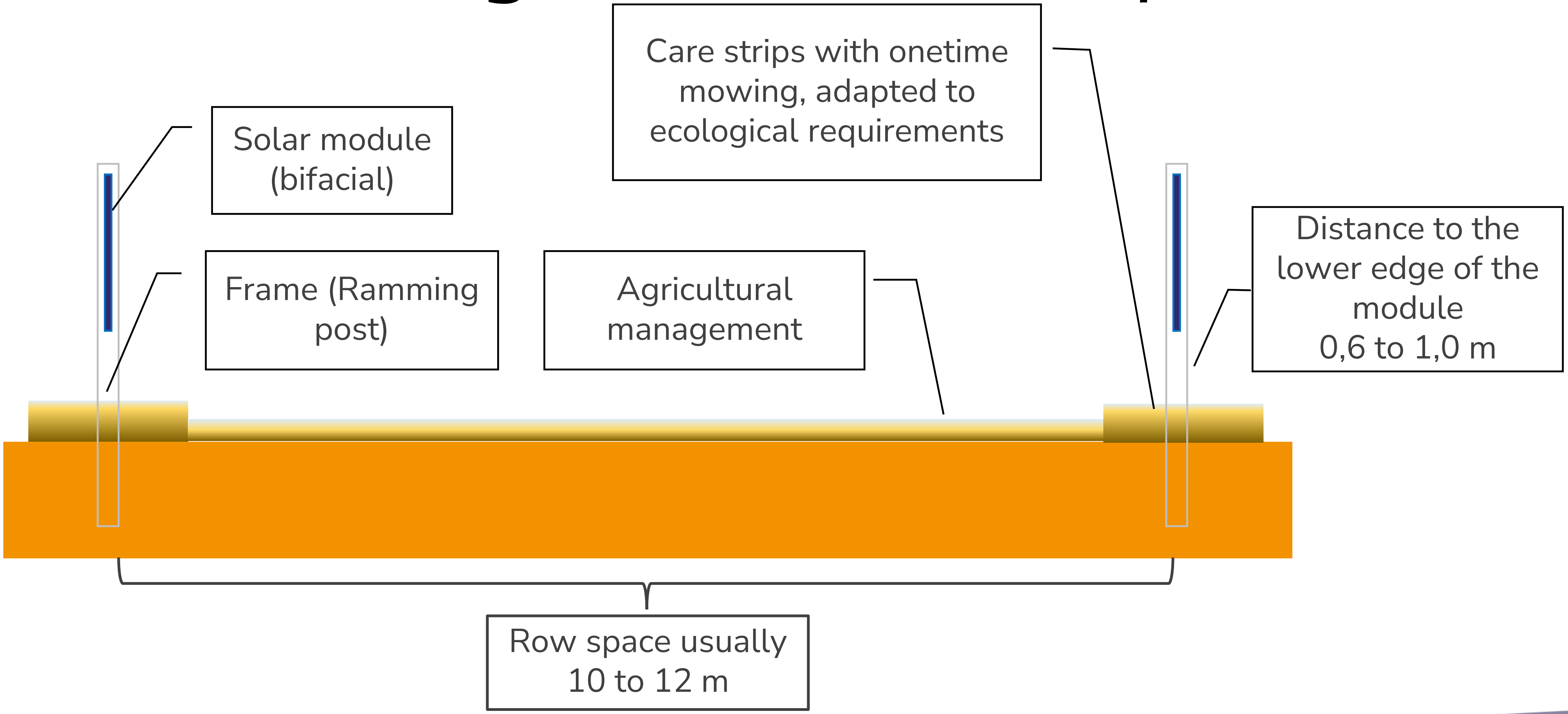
Back Up

Vertical bifacial Agri-PV – the concept

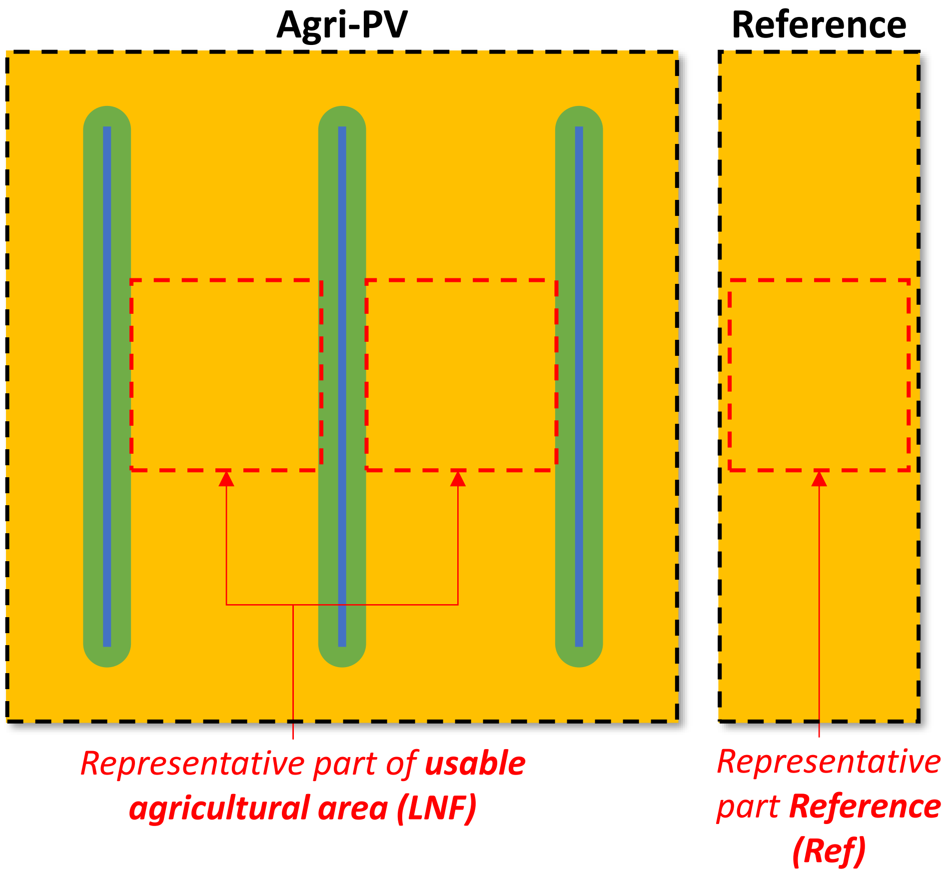


21

Agricultural yields

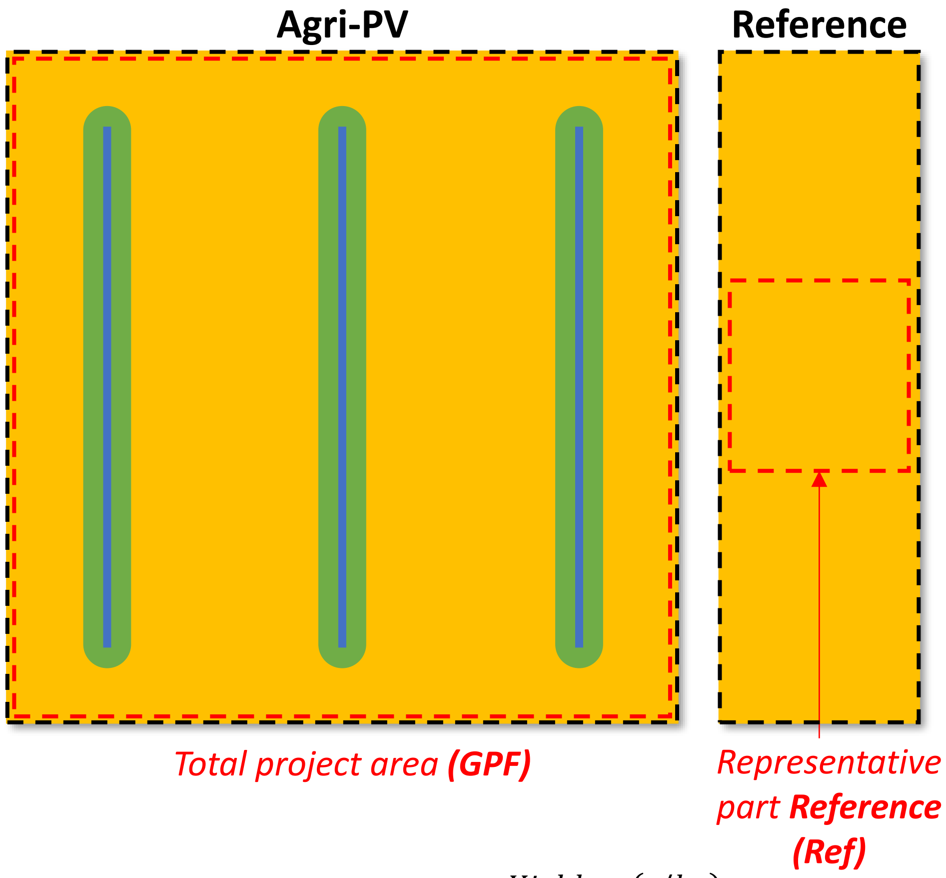
Plant vs. area yield

Crop yield *(excluding land losses)*



$$\boldsymbol{Crop\ yield}\ (\%) = \frac{Yield_{\boldsymbol{LNF}}(t/ha)}{Yield_{Ref}(t/ha)} * 100$$

Area yield *(including land losses)*



$$\boldsymbol{Agric.Area\ yield}\ (\%) = \frac{Yield_{\boldsymbol{GPF}}(t/ha)}{Yield_{Ref}(t/ha)} * 100$$

$$= Crop\ yield\ (\%) * \left(100\ (\%) - Land\ loss\ (\%)\right)$$