Agrivoltaics based on vertical bifacial PV

Use cases and practice

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Agenda

N2S vertical bifacial: Basics

Use Case: Maintaining lang use

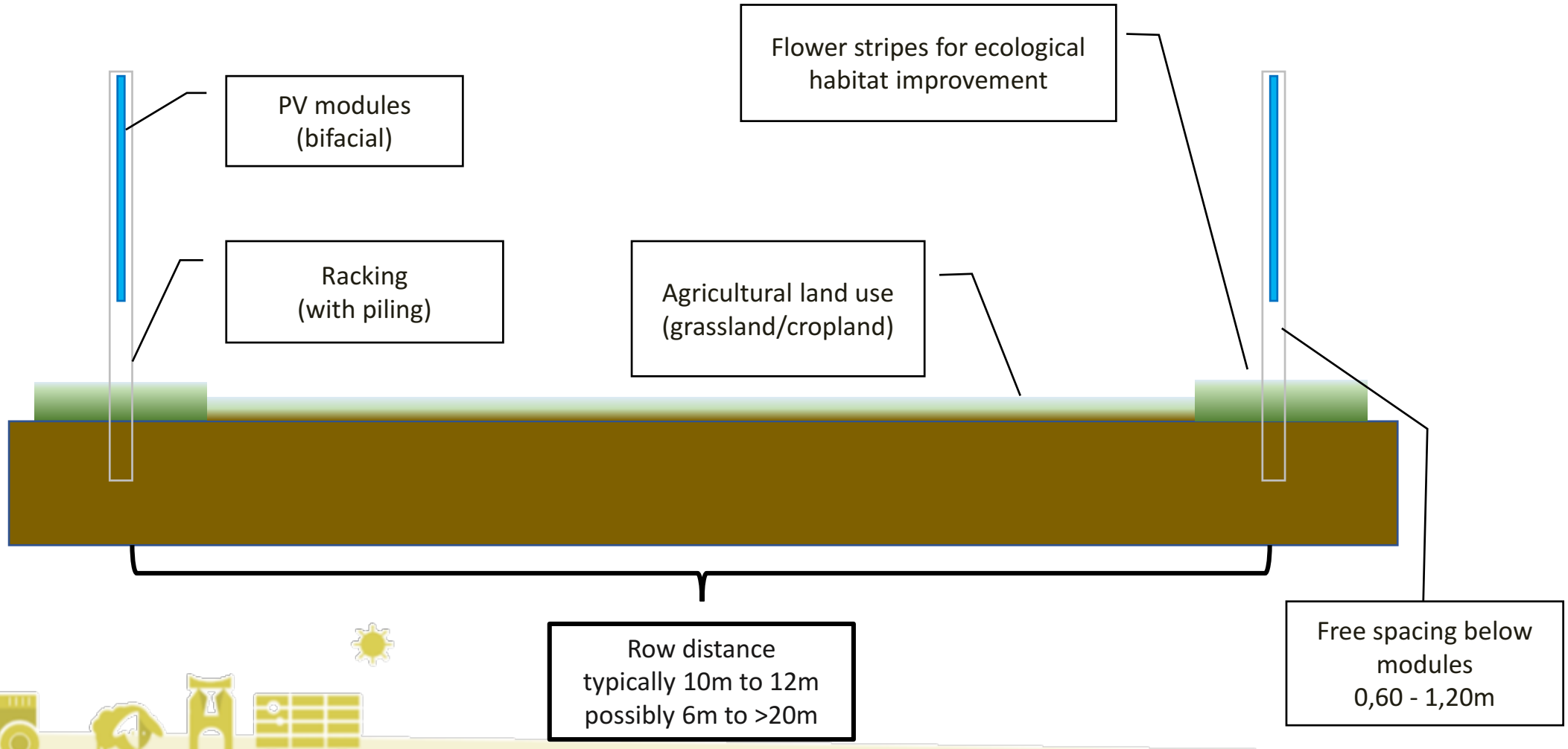
Use Case: Limited grid connection

Use Case: Fencing

Best practice: Solarpark Wellingen

Vertical bifacial Next2Sun PV plant at Donaueschingen (4,1 MW)

Schematic view on a Next2Sun PV plant



Comparison N2S vs. conventional PV

- **Specific yield** is typically 5-10% higher for vertical E-W than for conventional PV (South, 20°)
- **Installed power** on a given overplanned area is by a factor 2-3 lower than for conventional PV, due to large row spacings
- **The effective land consumption** (m^2 land consumption per m^2 module area) goes down from ~2,00 to ~0,50 to 0,005 (depending on the definition)
- **The effective market value per kWh** is about 0,3 ct/kWh higher than for conventional PV

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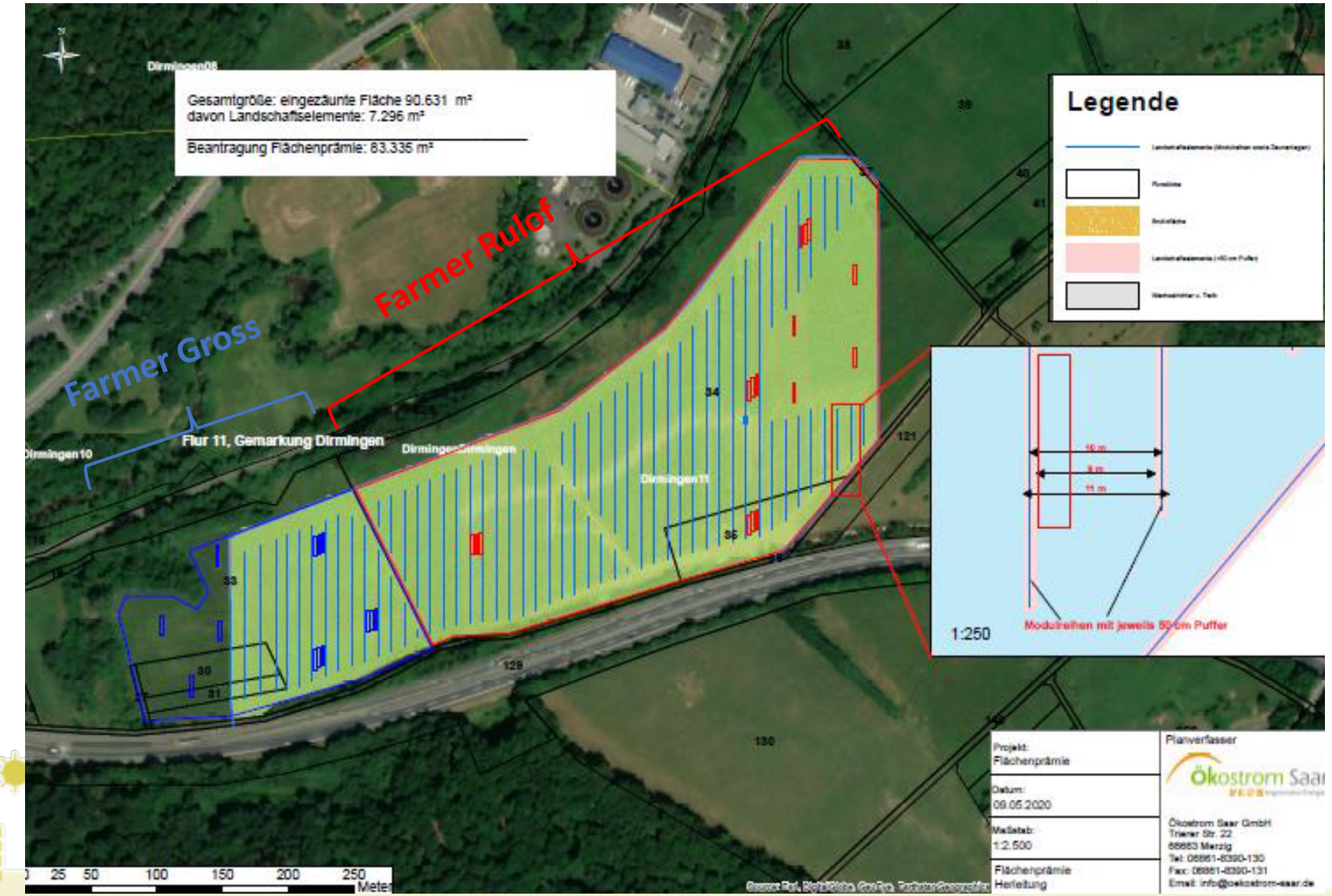
Use Case: Maintaining land use

- **Vertical bifacial Agri-PV** allows for using agricultural land for PV - without ceasing agricultural use
- Reference: Conventional PV on a given area
  - PV Power ~1MW/ha, agricultural use no longer possible
- Agri-PV: Vertical bifacial PV on the same area
  - Power ~0,4 MW/ha, agricultural use can be maintained
  - Grassland use (pature, silage, hay) with very few restrictions, and better agricultural yield in many cases
  - Cropland use needs some adaption on both PV and agricultural sides

Hay harvest SP Dirmingen 2020

Study design:

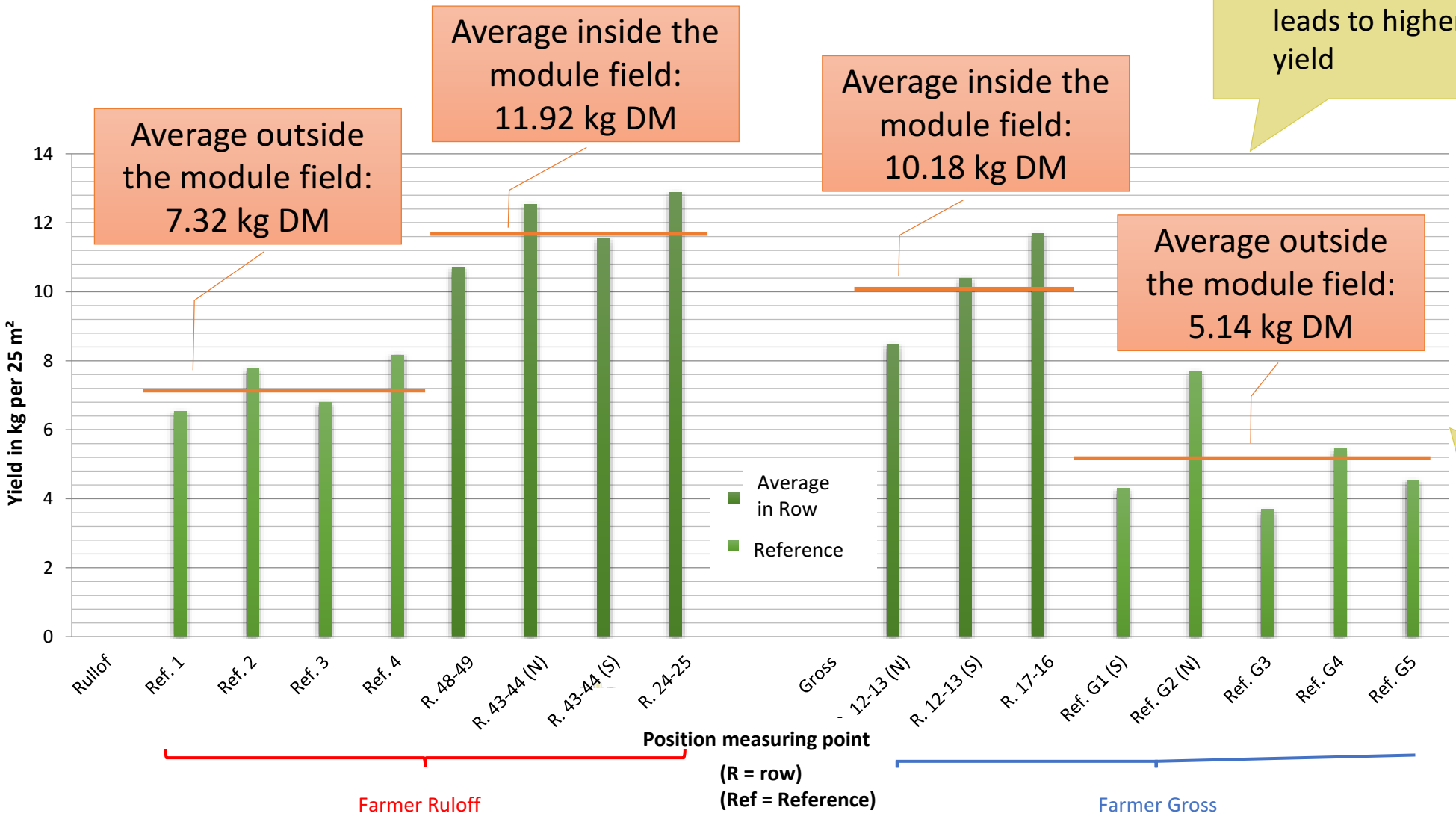
- Sampling on 8 reference areas (area without modules) and 7 areas within the module rows.
- Three test areas next to each other within the module rows (in the middle and on both sides next to the modules).
- The growth of each area (approx. 2.50 x 10 m) is collected and weighed in a "big bag" immediately after mowing.
- Sampling from each test area (feed quality).
- One blow (approx. 7 hectares = 17,3 acres), separately managed by two farmers (Rullof, Gross).
- Only one single harvest year.



Hay harvest SP Dirmingen 2020

The key fact:

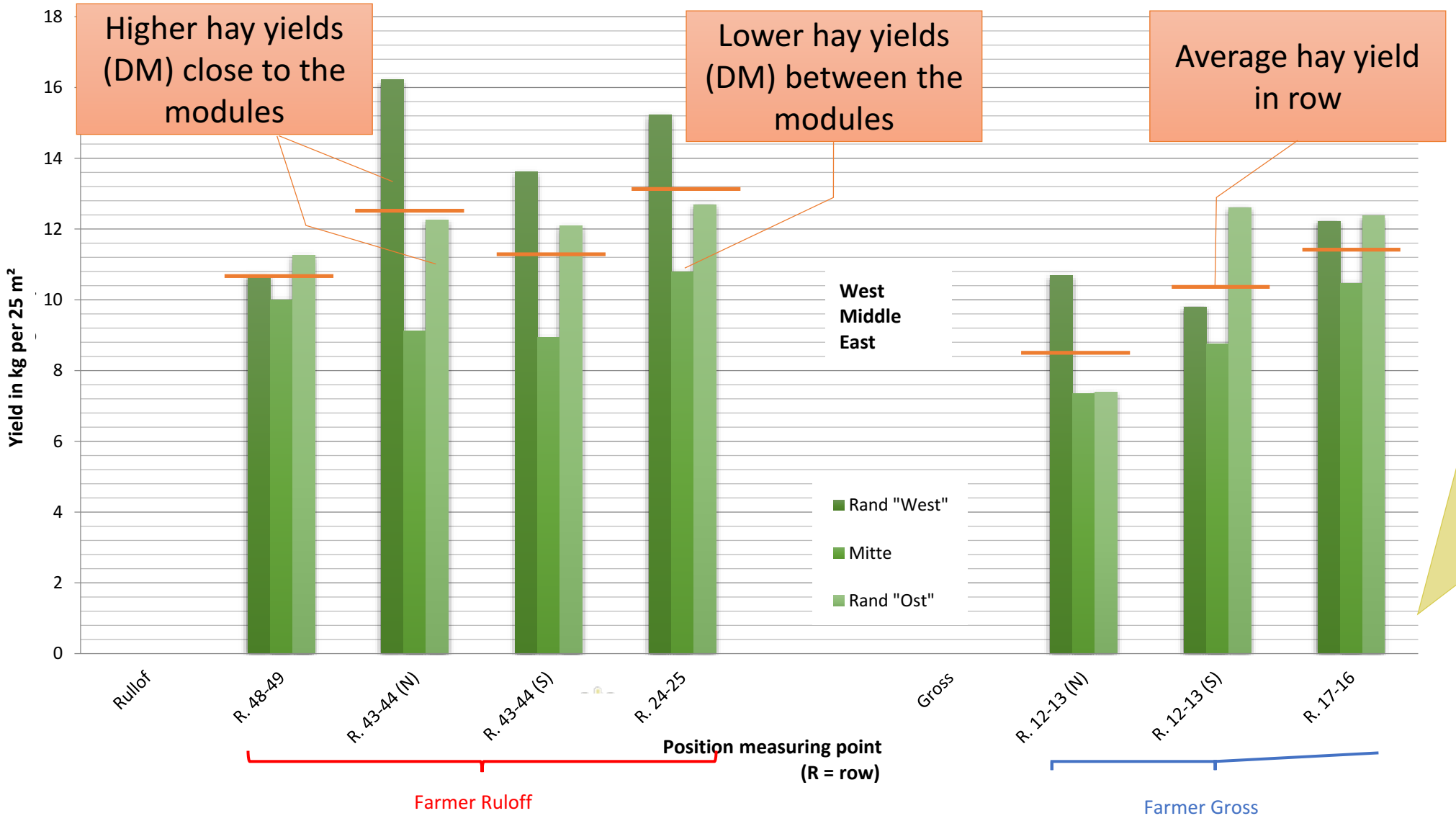
- Shadow from the modules leads to higher yield



Our results:

- Every measuring point inside the module series (average in row) is higher than every measuring point outside.
- Minimum additional hay yield (DM) inside the module field: +10%
- Average additional hay-yield (DM) inside the module field: +77 %

Hay harvest SP Dirmingen 2020



Results only inside the module series:

- We assume higher positive shadow effects close to the modules (West & East) and lower effects in the middle.
- We need further research to find out if there are different effects of morning an evening sun.

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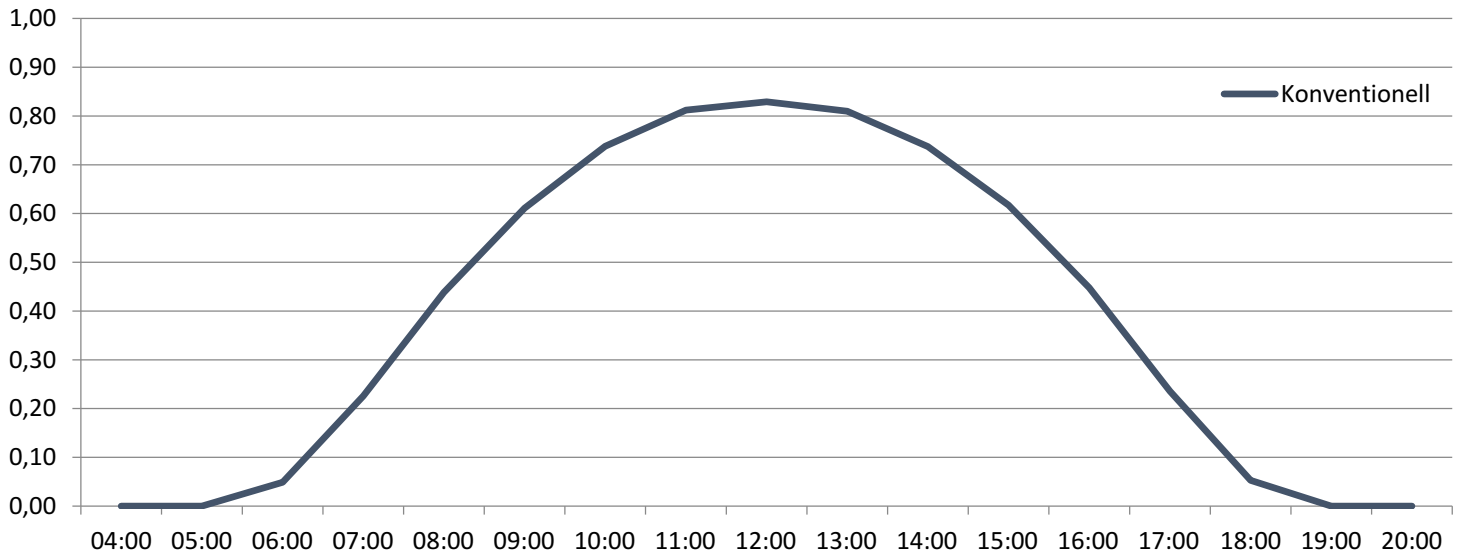
Use Case:
Pushing the limits of grid capacity

- **The combination of different orientations** allows for connecting more PV capacity to a limited grid connection
- Reference: Conventional PV limited by grid connection power
- Step 1: Combining conventional PV with vertical E-W
  - Power +29%, overplanned area +126%, land use -77%
- Step 2: Combining different vertical Orientations
  - Power +50%, overplanned area +250%, land use -65%
- **Looking at the facts for a given grid capacity of 10 MW:**

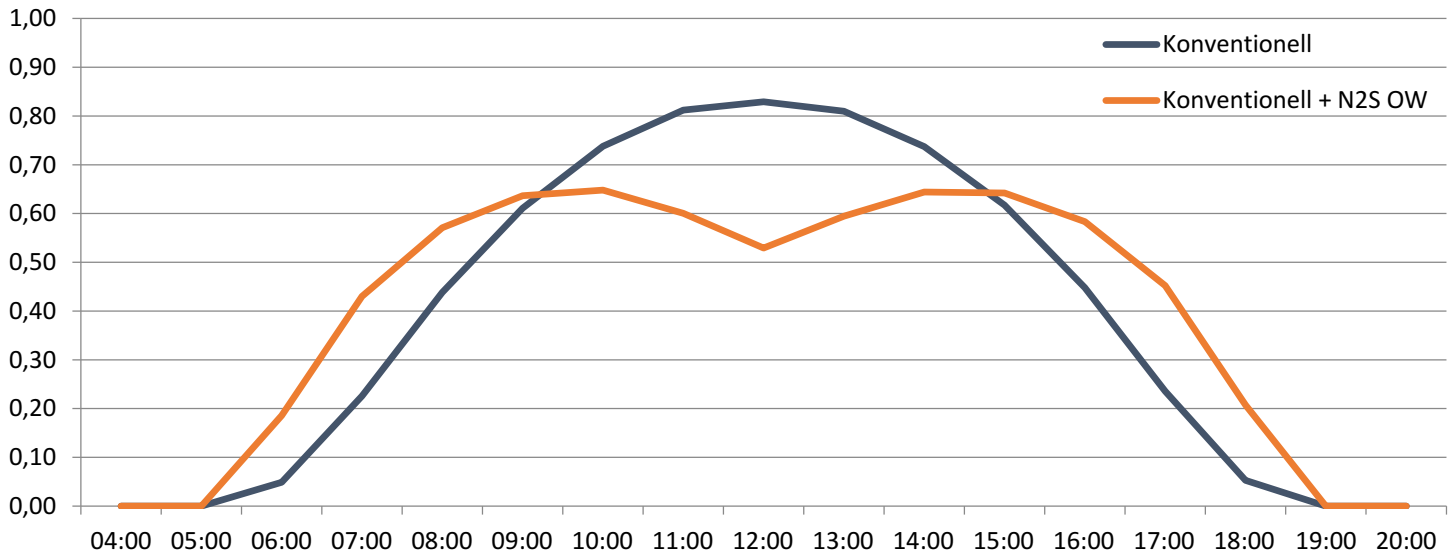
Limited grid: Reference

- Only conventional PV (fixed tilt, South, 20°)
- Grid capacity 10 MW means (@ cap loss < 1%)
  - 12,8 MW installed capacity
  - 13,1 GWh/a annual production
  - ~13 ha module field
- Generation profile (season: mid of april)



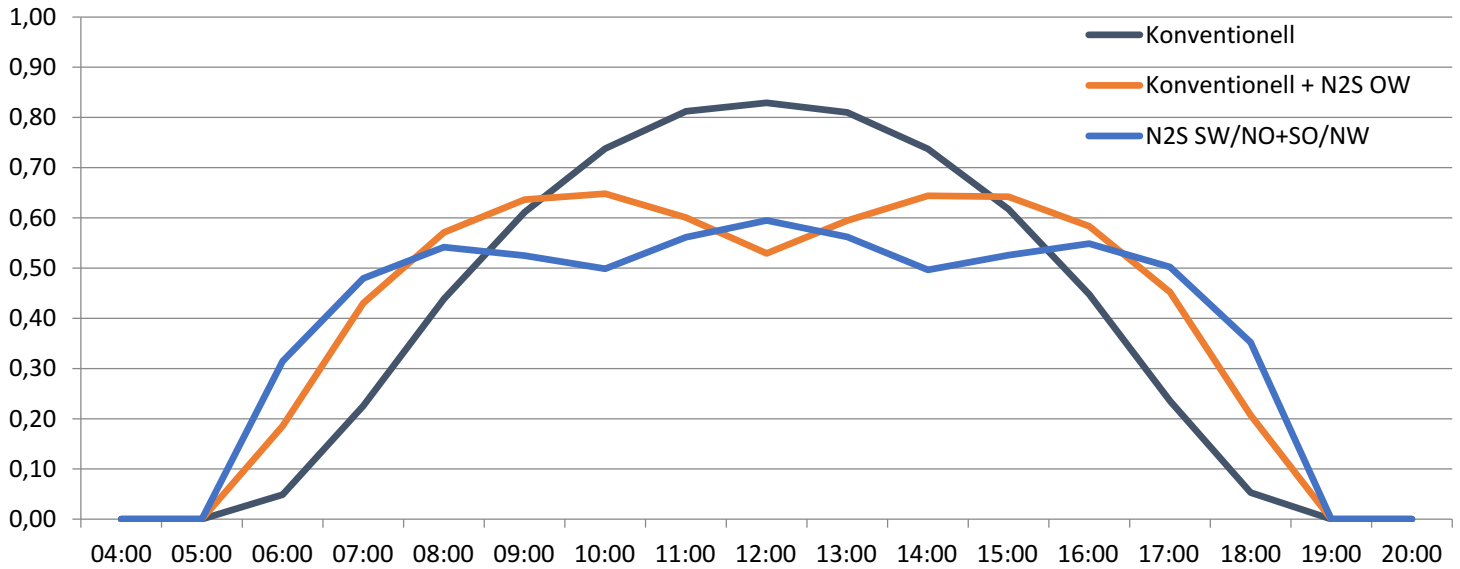
Limited grid: Step 1 – combination

- Combination of conventional PV and vertical East-West
- Grid capacity 10 MW means (@ cap loss < 1%)
  - 16,7 MW installed capacity
  - 17,6 GWh/a annual production
  - ~29 ha module field
- Generation profile (season: mid of april)

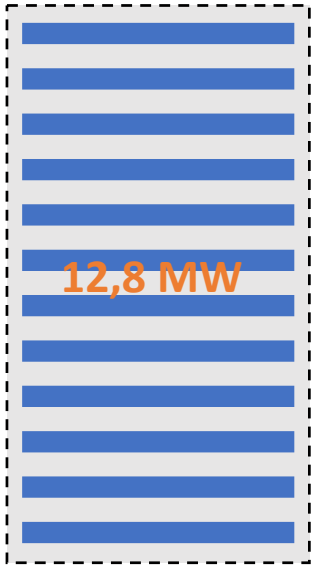


Limited grid: Reference

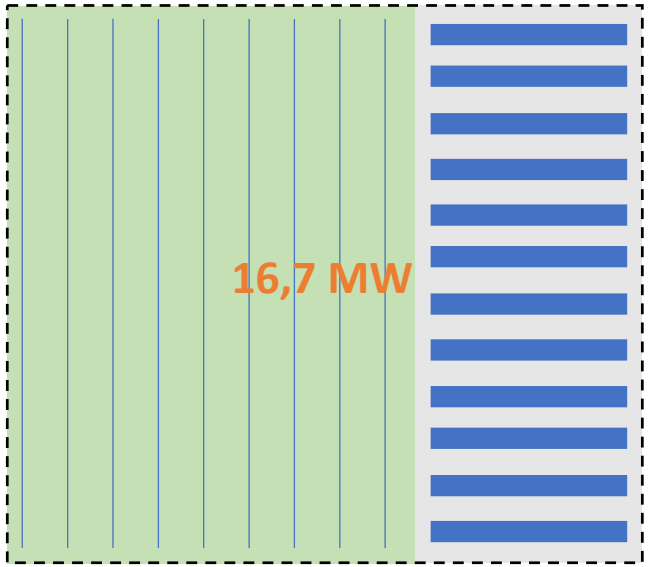
- Combination of vertical SW with vertical SE
- Grid capacity 10 MW means (@ cap loss < 1%)
  - 18,2 MW installed capacity
  - 19,9 GWh/a annual production
  - ~46 ha module area
- Generation profile (season: mid of april)



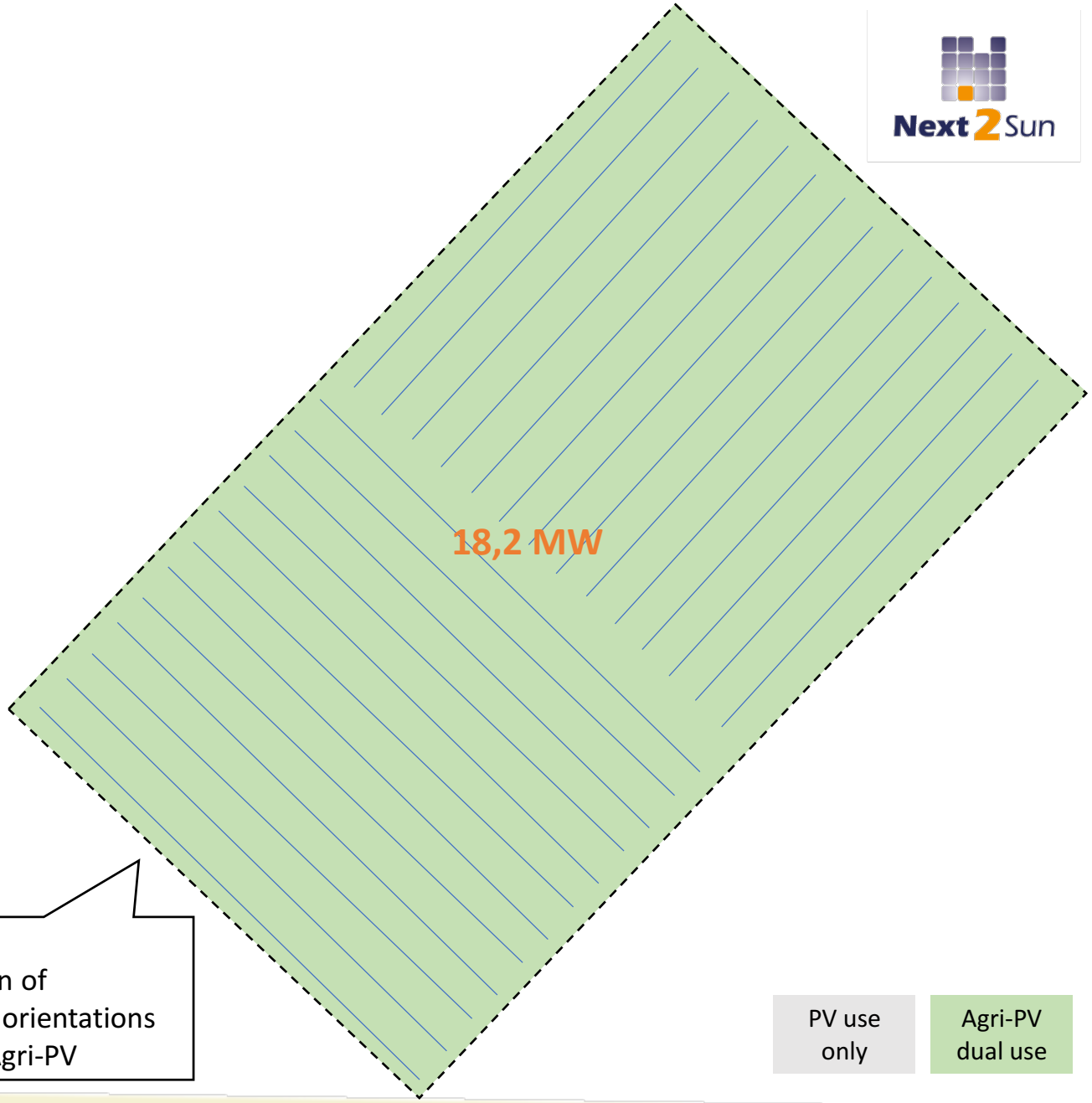
Schematic layouts



Reference:
Conventional PV only



Step 1:
Combination Conventional with vertical Agri-PV



Step 2:
Combination of Orthogonal orientations of vertical Agri-PV

PV use only

Agri-PV dual use

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Solar Fence:
Combining Fencing and Power generation

- Adding power to
  - Farms
  - PV plants
  - Industrial/commercial sites
- No additional land consumption
- Saving cost for fencing
- Interesting generation profile (e.g. for own consumption)

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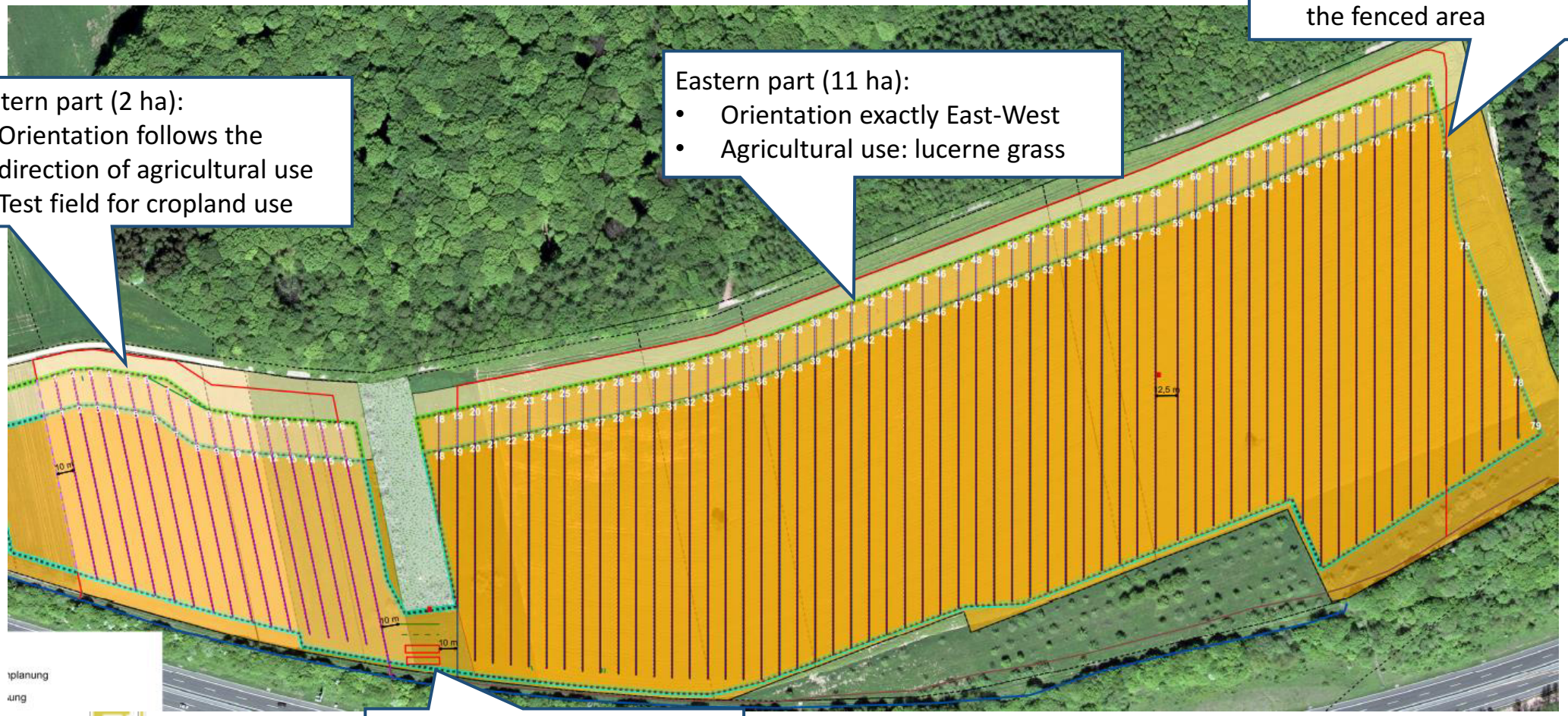
- Agri-PV Project in Merzig (Saarland)
  - 5 MW installed capacity
  - 5.500 MWh/a annual production
  - 13 ha module area
- Realisation in Q3-2021
- First N2S plant on cropland
- Agricultural use:
  - 10 ha lucerne grass for animal feeding
  - 2 ha experimental area (different crops, research studies)

Layout plan



Western part (2 ha):
- Orientation follows the direction of agricultural use
- Test field for cropland use

Eastern part (11 ha):
- Orientation exactly East-West
- Agricultural use: lucerne grass

Fencing
- Last „full“ row is used as „Solar fence“
- Some rows stay outside the fenced area

PV test field:
Gathering reference data
- N2S South-North
- Conventional PV

Economies & Comparison

Size: 5 MW	Conventional plant (reference values)	Next2Sun SP Wellingen	Comments
CAPEX (turnkey)	2,75M ~550 €/kW	**3,3M ~630 €/kW**	Additional cost: Modules&Racking
Annual yield	1.050 kWh/kW	**1.150 kWh/kW**	based on HJT cell technology
Revenues per kWh	fixed feed-in-tariff ~289k p.a.	**FIT+ 0,3 ct/kWh ~334k p.a.**	Higher revenue based on hourly EEX prices
Agricultural land loss	6 - 7 ha	**1,3 ha**	90% of the field can still be used
Overall OPEX of which: land lease	~65k p.a. ~12k p.a.	**~67k p.a.** **~18k p.a.**	Less greenkeeping&cleaning More land lease (abs.)
Gross profit	~224k p.a.	**~267k p.a.**	
IRR on equity (20a)	~4,5%	**~4,5%**	
Lifetime	30 yr	**30-40 yr**	Using glass-glass modules

Thank you for your attention!