7TH INTERNATIONAL CONVENTION
OF ENVIRONMENTAL LAUREATES
FREIBURG, GERMANY · 15 - 18 MARCH 2018

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- Stephan Schindele

Research Project Agrophotovoltaics, Fraunhofer Institute for Solar Energy Systems

„Agrophotovoltaics: Power and Food. Combining PV with Crop Harvesting“

FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE

Agrophotovoltaics (APV): Power *and* Food

Combining PV with Crop Harvesting

Stephan Schindele

Fraunhofer ISE

Presentation,

7th International Convention of Environmental Laureates

Freiburg, 17.03.2018

www.ise.fraunhofer.de

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AGENDA

- Problem
- Solution
- Outlook

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Problem

PV-ground mounted

- Requires (limited) arable land
  → land-use conflicts
- Cultural landscape is impacted
  → social acceptance problems
- Growing energy demand globally
- Energy sector responsible for 85 % of CO2-emissions

Agriculture

- Crops suffer from too much solar radiation
  → adaptation to climate change needed
- Increasing economic pressure on arable land → increasing land prices
- Water becomes/is a scarce good
- Growing food demand globally
- Agricultural sector responsible for 7,5 % of CO2-emissions

- Nuclear phase-put by 2022, phase-out of coal by 20??, ambitious RE-goals until 2050
- Arable land becomes scarce → resource efficient land-use becomes/is important
- High demand of intersectorial and transdisciplinary technology development

  → dual-use of arable land → Agrophotovoltaics (APV)

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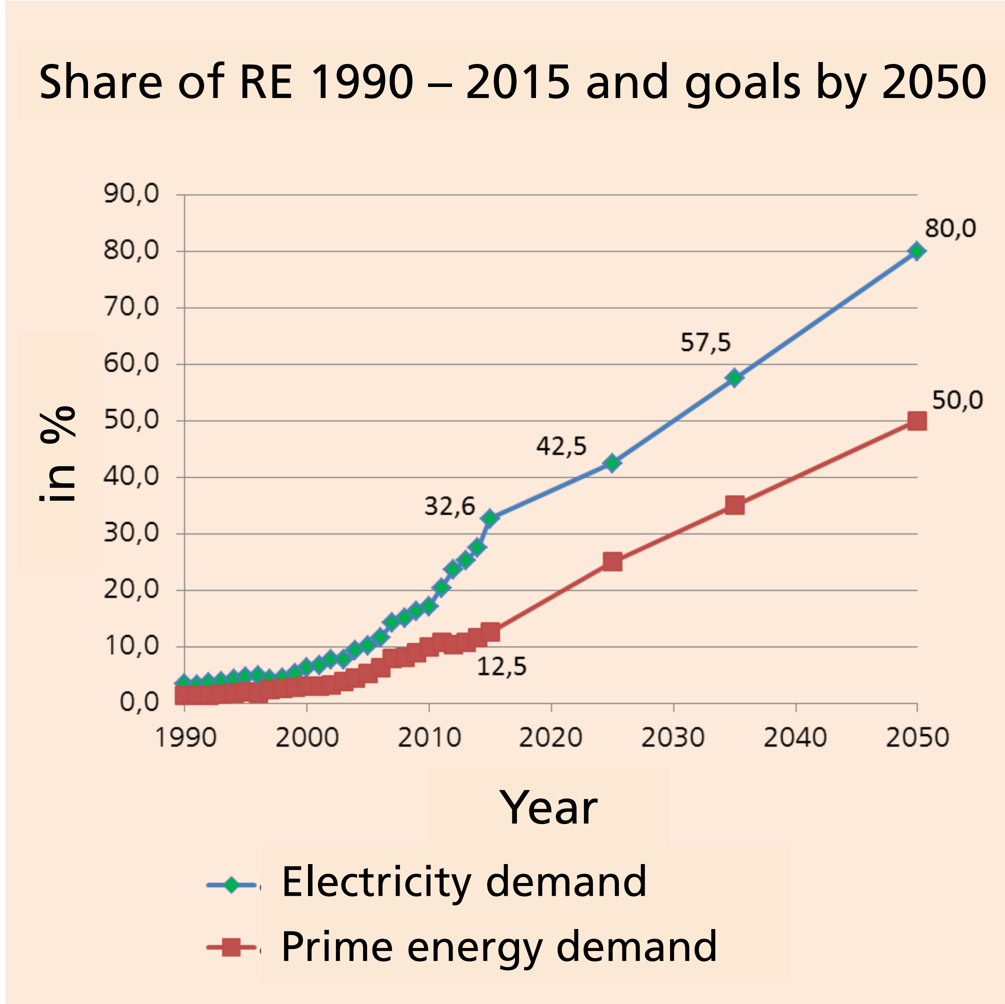
Problem: Case Study Germany
RE-targets until 2050

- Energy Transformation has only "recently" started
- Best sites for RE-implementation are already taken
- Energy efficiency targets are very ambitious
- Sector coupling: electricity sector merges with heat/cooling and transport sector
- Demand for land continues to be high → 18 % of arable land occupied for energy production
- Paris Agreement pressurizes political, societal, and business stakeholders



Source: AGEE-Stat, BMWi / own layout

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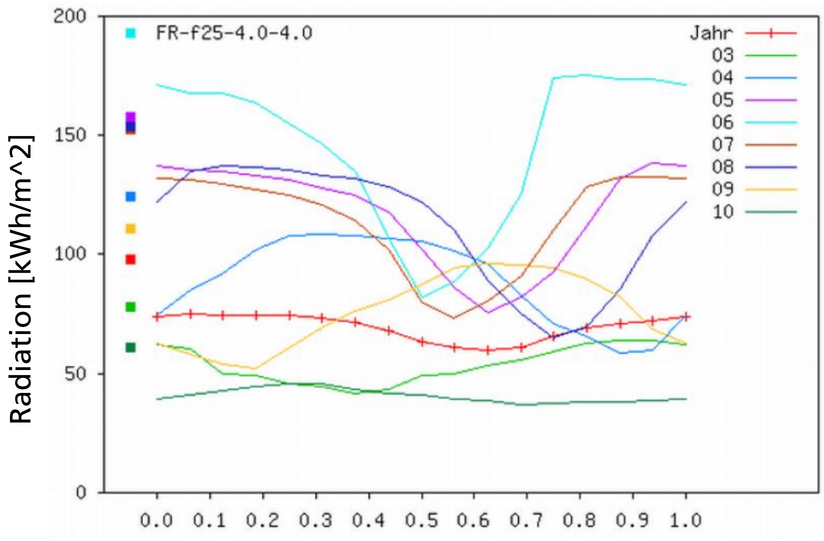
Solution: Fraunhofer ISE patent on lightmanagement

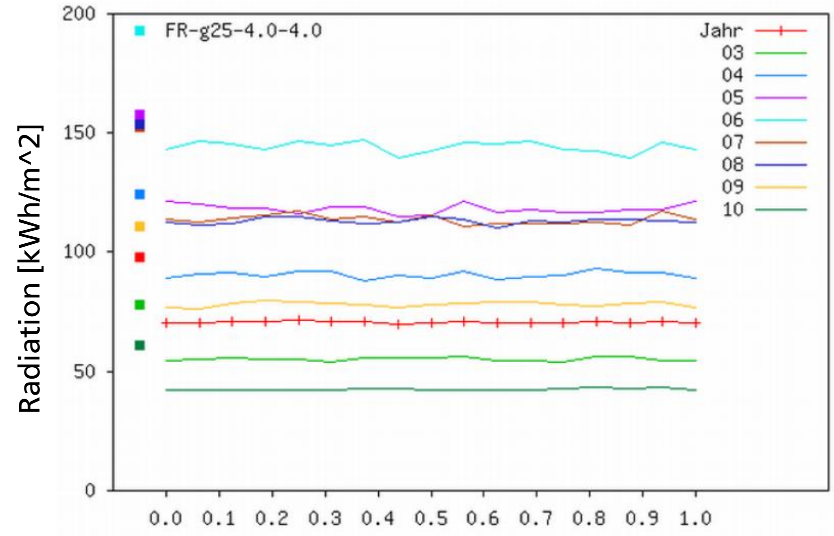
Simulations of radiation on ground level under APV

Orientation: South



Space between two module rows

Orientation: South-east or South-west



Space between two module rows

- Homogeneous distribution of radiation underneath APV possible
- Sufficient radiation during vegetation phase of crops feasible
- Electricity losses compared to South orientation are low: -5 %
- Peak-load shifted into morning or afternoon hours due orientation

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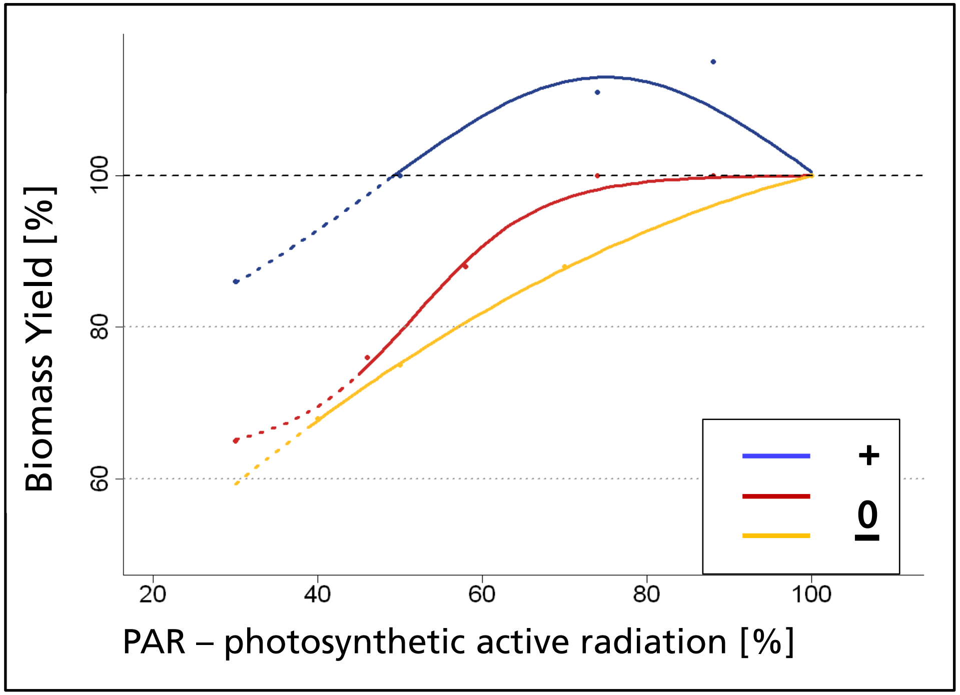
Solution: Case study Germany
Suitable crops – Part I



Category	Crops
+	Salad
0	Rape & Barley
-	Corn

Source: Fraunhofer ISE

- Shade tolerant crops exist
- Increase in yield and quality improvement through shading is possible

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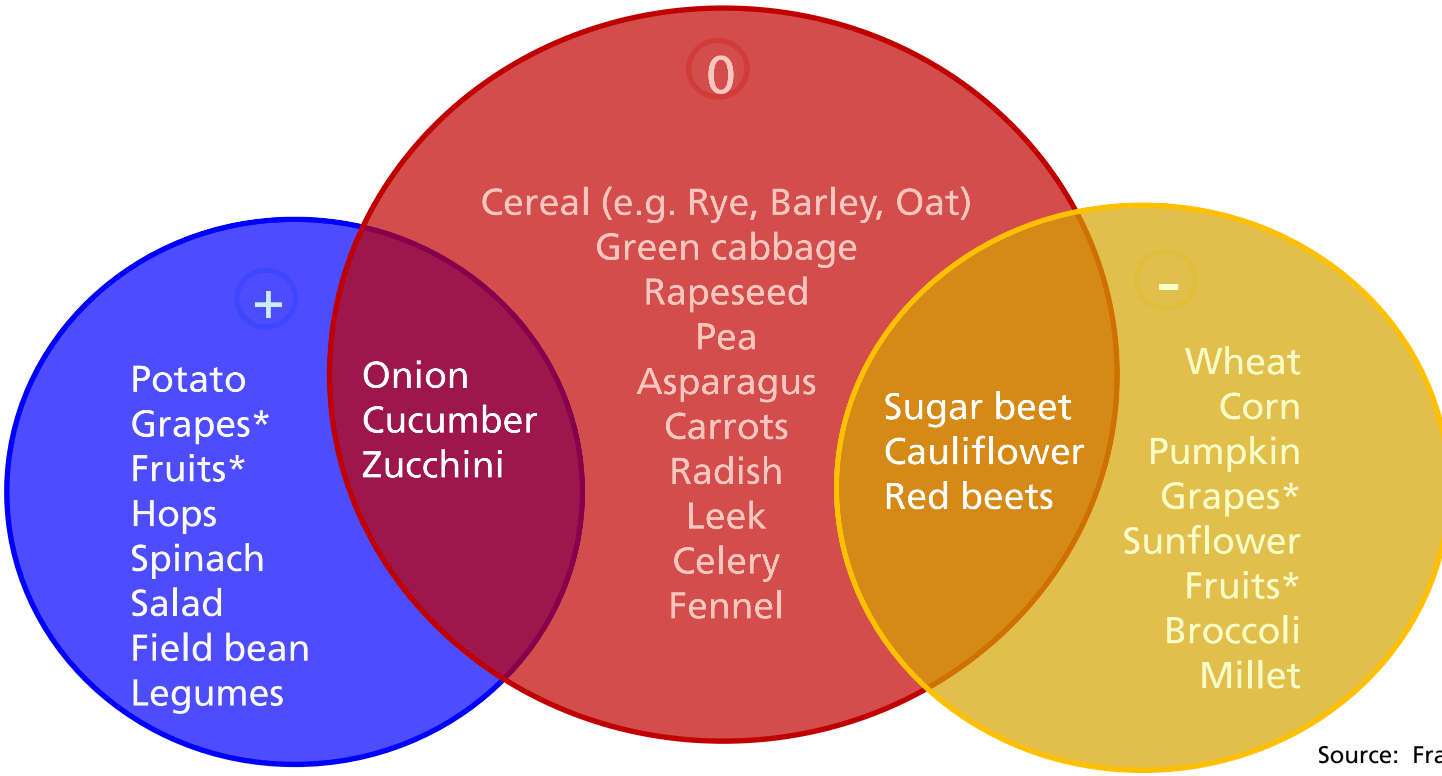
Solution: Case study Germany
Suitable crops – Part II

Classification of Germany’s most relevant economic (food) plants in agriculture:



Source: Fraunhofer ISE

*depending on the type

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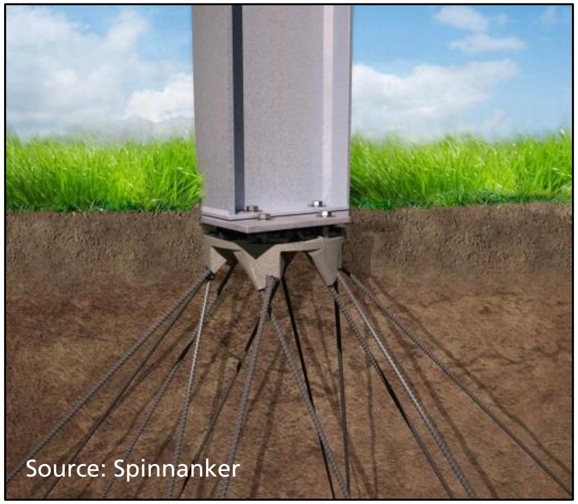
Solution: Case study Germany
APV-Prototype in Heggelbach, Proof of Concept

- Bifacial PV-Modules, Spinnanker fundaments, Lightmanagement
- Arable land not considered in EEG market-based mechanism → no FiT
- Only 5 % of arable land is lost/sealed → yet, 100 % of land accounts sealed
- Farmer does not receive EU-subsidy anymore for his land
- Farmer receives land lease and uses > 40 – 60 % of the electricity
- Winter wheat, clover grass, potato and celery → approx. 15 % less yield


Source: Hofgemeinschaft Heggelbach


Source: Spinnanker

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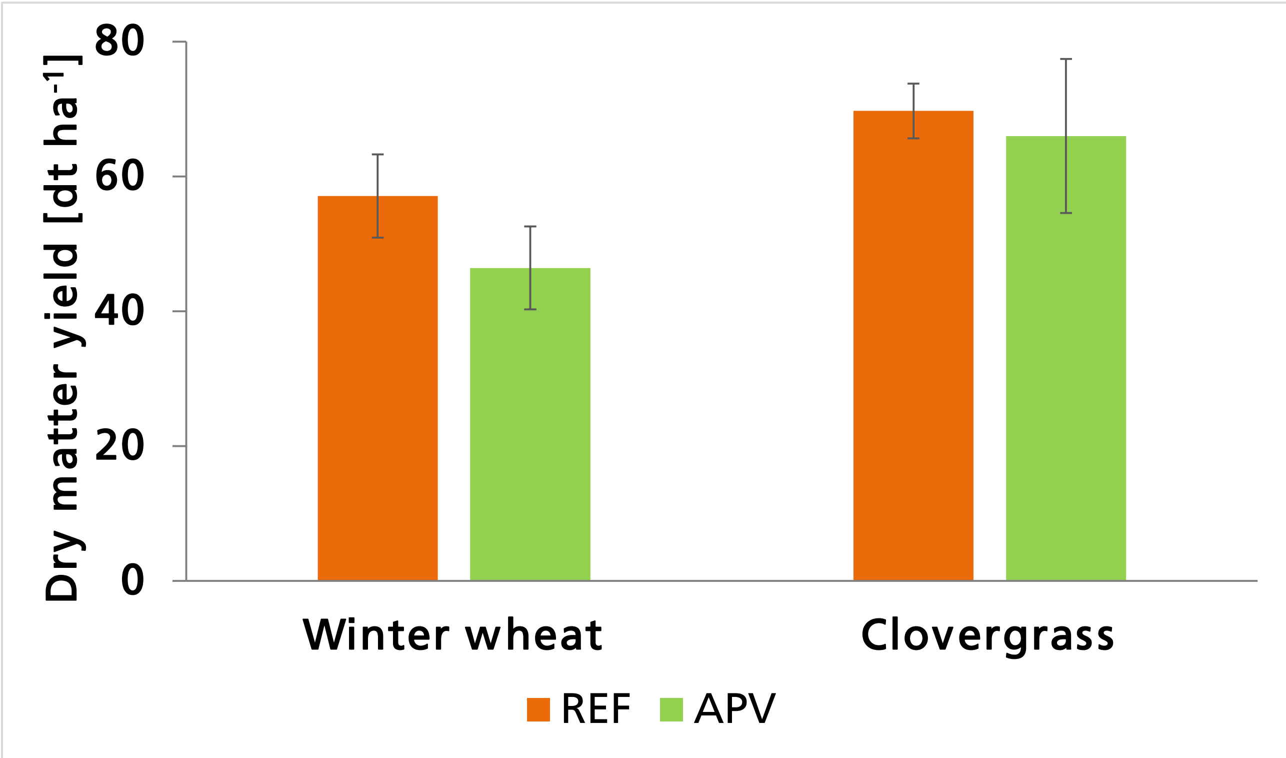
Solution: Case study Germany

First harvest: Winter wheat and Clovergrass



Source:
University of Hohenheim

- Winter wheat: yield reduction by 19 % under APV
- Clovergrass: yield reduction by 5 % under APV (4 cuts)

UNIVERSITÄT HOHENHEIM

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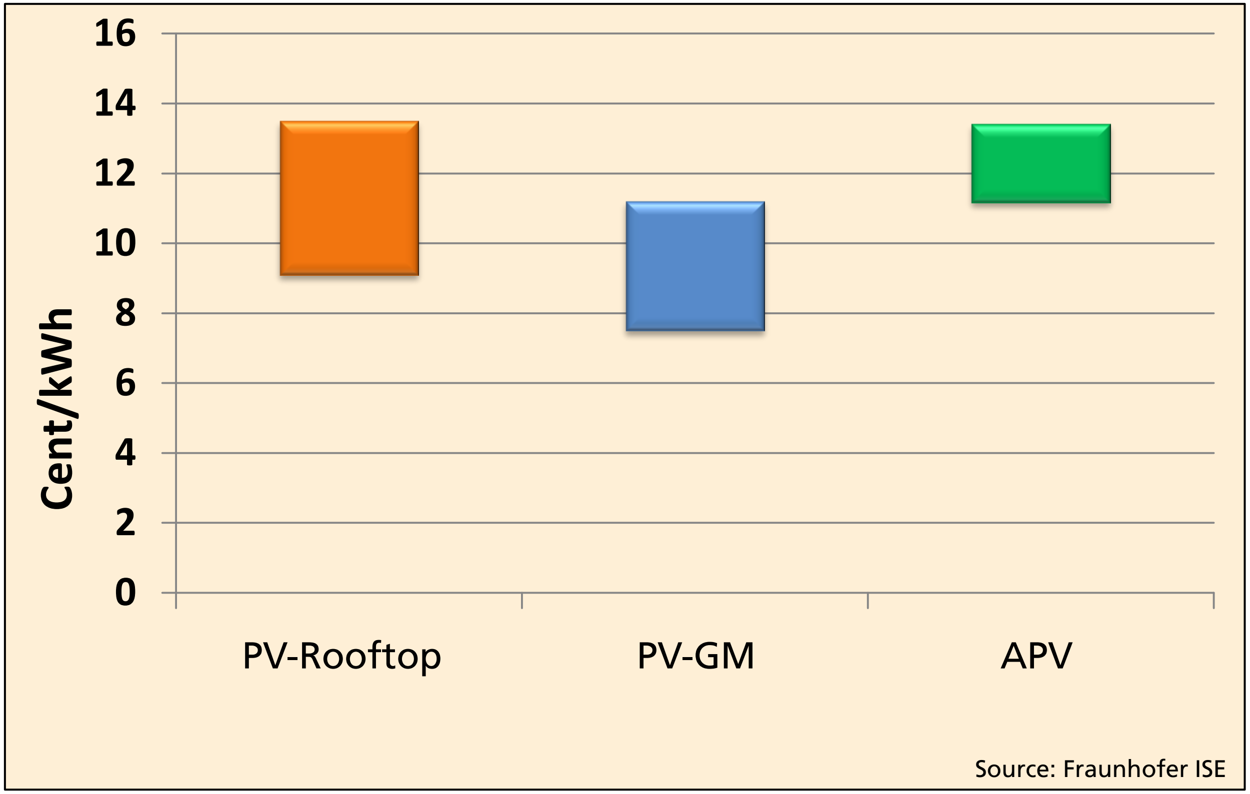
Solution: Case study Germany

APV-Levelized Cost of Electricity (LCOE) compared to PV



- PV-Rooftop:
  10 – 750 kWp
- PV-GM:
  750 kWp – 5 MWp
- APV:
  1 MWp
- Solar radiation:
  1000 – 1200 kWh/(m²a)

- APV (Prototype) cannot (yet) compete with PV-GM
- APV is already today competitive with small PV-rooftop installations

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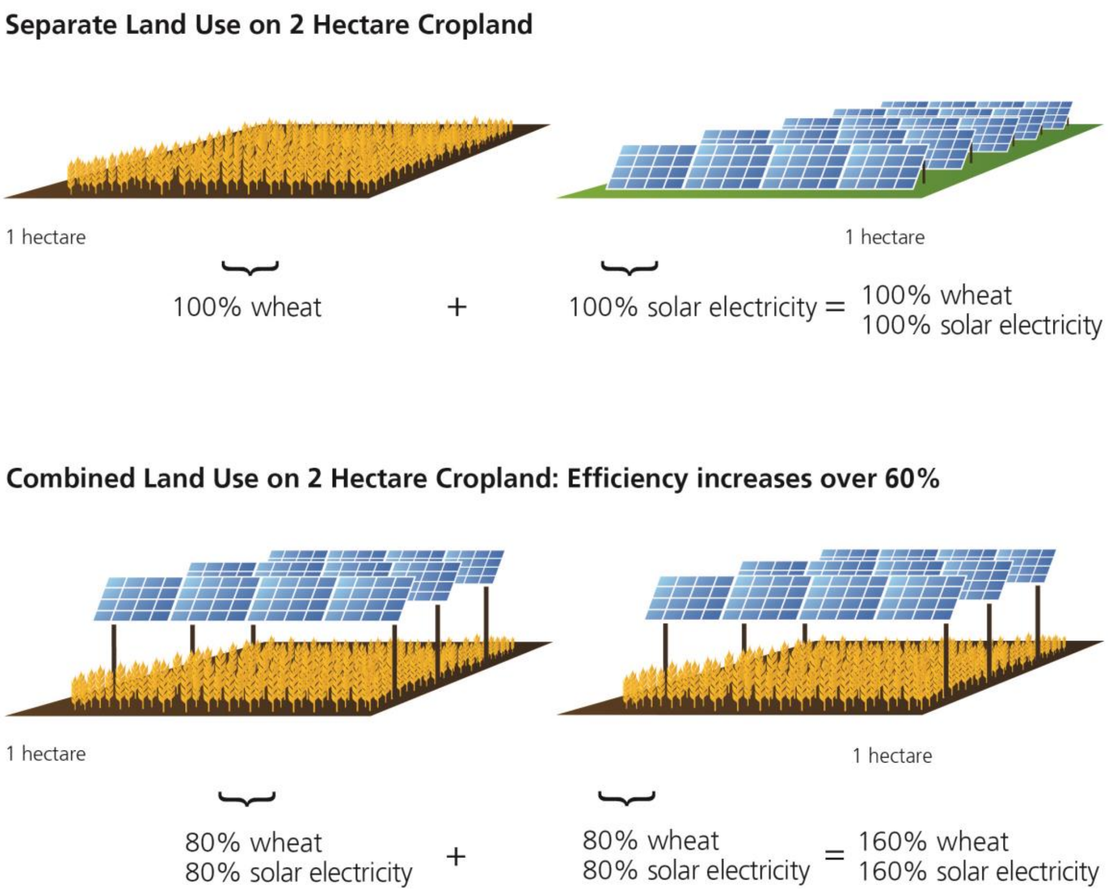
Solution: Case study Germany
Increase of land-use efficiency by over 60 %



Source: Fraunhofer ISE

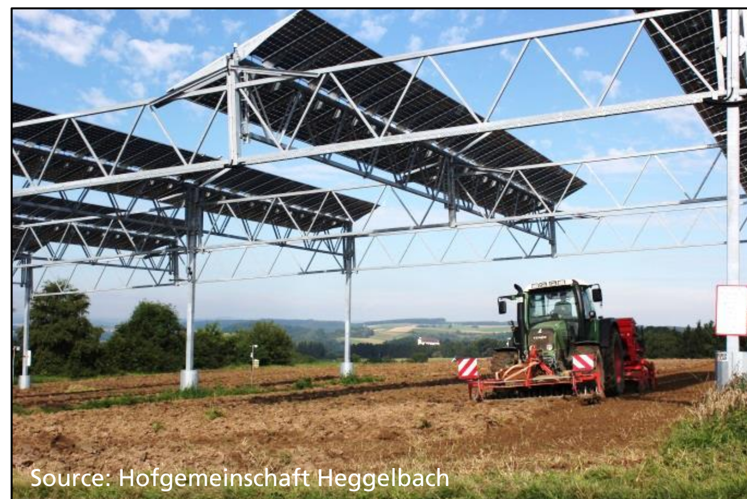
- PV-cropping is feasible and synergies generate additional income for farmers

Solution: Case study Germany

APV Potential: 1 hectare - 1 APV plant - 1 farmer

- Basic information/data:
  - 300.000 farmers
  - 13.300.000 hectares arable land
  - 700 kWp APV on 1 hectare land
  - 42 GWp total PV capacity installed by 2017
  - Between 250-300 GWp PV needed to meet NDC-goals

- Calculation on the APV potential:
  - 300.000 ha = 210 GWp APV
  - 2,3 % of arable land required
  - Very decentralized and evenly distributed


Source: Hofgemeinschaft Heggelbach

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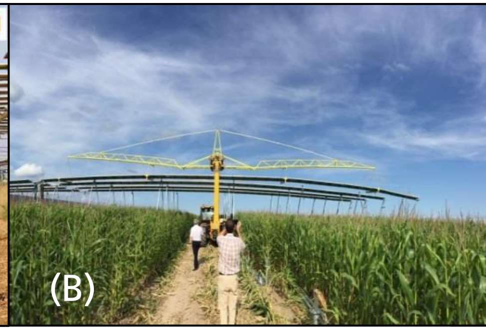
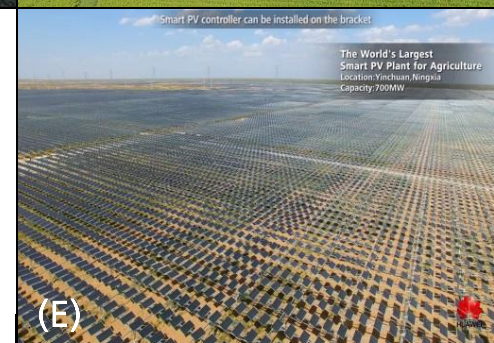
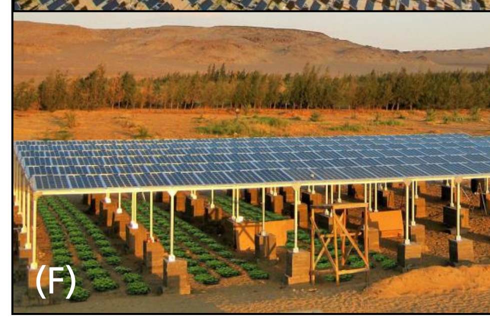
Global problems, global solutions, global market trends
Best practice examples of APV worldwide







- (A) Italy, R.E.M. Spa, 3x 3 MWp each, 2011
- (B) France, Straßburg, 300 kWp, E. Gimbel, 2016
  - Innovation auction: 45 MWp APV between 2017 – 2019
- (C) Chile, 3x APV-systems, Santiago, Fraunhofer CSET, 2016
- (D) Japan, Solar Sharing, Ministry of Agriculture, Forest and Fishery, Higashi, 2013, > 600 APV systems installed
- (E) China, Ningxia, 700 MWp, Huawai, 2016
- (F) Egypt, SEKEM, Almaden, Kairo, 90 kWp, 2017

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Outlook
APV-Vision

- Increase land-use efficiency
  - Farmers that produce energy <u>without</u> reducing food production
- Local value added
  - Farmers supplying themselves and their local neighborhood with electricity, heat, and fuel for transportation (P2G)
- Electrification of land-use machinery
  - Replace diesel-fuel with APV-electricity
  - Implementation of agrar-robotics
- Landscape integrated PV (LiPV)
  - Colored PV
  - Landscape modelling
  - Greening the desert

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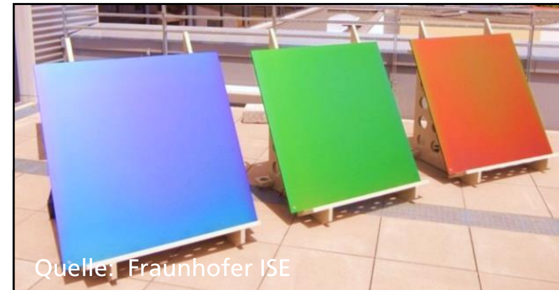
Outlook
APV innovation process: next steps

- **Technology-Push**
  - Horizontal Level = Diversification of APV

    e.g. vegetable, fruit, berries, wine, herbs, animals, hop, and aquacultures, etc.
  - Vertical Level = Innovation potential APV

    e.g. organic PV, spectral analysis, colored PV, construction, water-irrigation, storage, etc.
- **Demand-Pull**
  - Create a small APV-market, 40 MWp/a triggering industry innovation
  - Technical/scientific monitoring/analysis
  - Quality assurance and certification
- **Technology Transfer into other markets**


Quelle: Fraunhofer ISE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Source: Sahara Forest Project SFP Jordan

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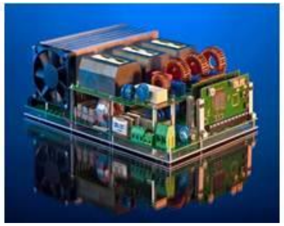
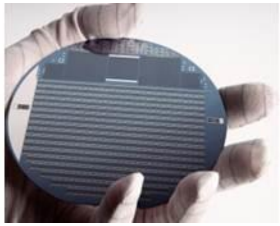
Thank you very much for your attention!

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