HORIZON SCANNING ALERT

Agrivoltaics, shielding crops with PV panels

What is the concept?

***Agrivoltaic systems* cover crops with photovoltaic panels and share the sunlight for co-production of food and electricity on the same piece of land** [1]. Other denominations include *agrivoltaics* [2], *agrophotovoltaic* [3] and *agri-PV*[i].

Though this may impose physical constraints on electricity and/or food production in some climates and economic constraints, it may enable a more efficient land [4, 5] and light use [6 - 8]. Other synergies and benefits, listed below, are currently investigated, with the more advanced concepts undergoing applied research, field testing and demonstration.

How it could be used: Implementation options

Ongoing tests focus on the use of readily available PV panels for covering open fields, in more or less tight meshes [9, 10]. Research also looks into the use of alternative structures in open fields [3, 11], the covering existing greenhouses [7, 12] or marine environments for floating PV farms [13], potentially used with aquaculture[ii]. Innovative PV technologies [1, 14-17], such as thin-films, would also enable the design of alternative “greenhouses”.

What are the added values: Synergies

By enabling the **co-production of food and electricity through sharing light and land**, *agrivoltaics* aims to optimise the use of both resources. Besides resource efficiency, the symbiosis of PV technology and agricultural production can also help achieve **higher crop yields or enable the use of different crops** through protection from heat [18, 19] or droughts [20-23]; **more efficient electricity production** by cooling PV panels [12, 24]; better environment and biodiversity [26], though also affecting pests due to higher moisture [25]; **resulting economic and social impacts** [2, 26-31].

Why is it potentially significant

Cost decrease of PV systems enables the technology to reach grid parity as evidenced by increased deployment. (Ground) solar farms are also emerging, benefiting from economy of scale. However stand-alone PV is land-intensive [32]. Agrivoltaics enables the deployment of PV panels onto agricultural surfaces and opens the door to economy of scale.

Further food production also calls for land availability. In densely-populated areas sharing scarce land areas can lead to overall efficiency gains, while in (semi)arid areas partially shading plants with PV may increase crop yields [33].

Agrivoltaics targets two societal issues: a **sufficient supply of food** and the **decarbonisation of the economy**. It also opens opportunities for rural economies and communities [34].

Potential relevance for EU action/objectives

The **European Green Deal**[iii] aims to decouple economic growth from resource use, and **calls for a rethink and integration of numerous policies including clean energy supply, large-scale infrastructure, transport, food and agriculture.** *Agrivoltaics* fits under this heading, combining renewable energy with food systems, therefore touching on energy, food, agriculture and rural policies.

How to proceed: Way forward

A thorough review of ongoing research would shed light on the challenges being currently investigated especially those aiming at developing synergies between the food and energy sectors. *Agrivoltaics* could be supported by EU R&D on crops (e.g. identification of suitable crops [35, 36] and the impact on yields and profitability [12, 19, 37-40]) and through the demonstration of different PV concepts [1, 14-17].

These research avenues imply following-up on the future work indicated by the above referenced papers, such as the validation of Dye-Sensitized solar Cells [16] or the performance assessment of crops at different agro-climatic zones through field testing [36]. This latter point would then validate the hypotheses included in models [37] and ascertain the potential of agrivoltaic farming throughout the globe [38]. Other aspects foreseen for investigation include the resilience of food and energy systems linked to heat and drought [24] and the consequence of preserving agricultural land against urban growth patterns [30].

Current policies may need amending, e.g. licences for the built environment, pooling RES and CAP subsidies towards demonstration projects. Communities of practices (e.g. from/for scientists to/for farmers) could also pool resources together and disseminate knowledge available[iv], beyond *agrivoltaics* towards Renewable Enery Technologies [27]. These aspects aim at mitigating risks associated with agrivoltaics, specifically its economic viability and public acceptance. The consequences of its large scale deployement should be assessed, though the energy sector already benefits from studies focusing on PV technology.

Supporting technical information

Agrivoltaics was initially introduced to the JRC Horizon Scanning community[v], through an article retrieved by the JRC Europe Media Monitoring Tool. Retrieval of further news articles - such as listed below - hint at broad geographical coverage of the ongoing research and interest related to *agrivoltaics*.

In the frame of JRC Horizon Scanning exercise, *agrivoltaics* was deemed innovative and potentially having a significant impact. Therefore a dedicated workshop took place on 20 December 2019[vi]. Among the conclusions, participants called for a literature review to better understand ongoing research.

40 scientific articles related to *agrivoltaics* were subsequently retrieved from Scopus listed in ”Literature scan” below. This scan indicates for each paper the scope and approach. The annual count of publications, displayed in the bar graph below, suggests growing research interest in the emerging field of *agrivoltaics*. This interest is also demonstrated in upcoming events.[vii][viii]

The integration of PV panels onto greenhouses and the co-production of electricity with acquaculture and grazing animals are not addressed in this factsheet.

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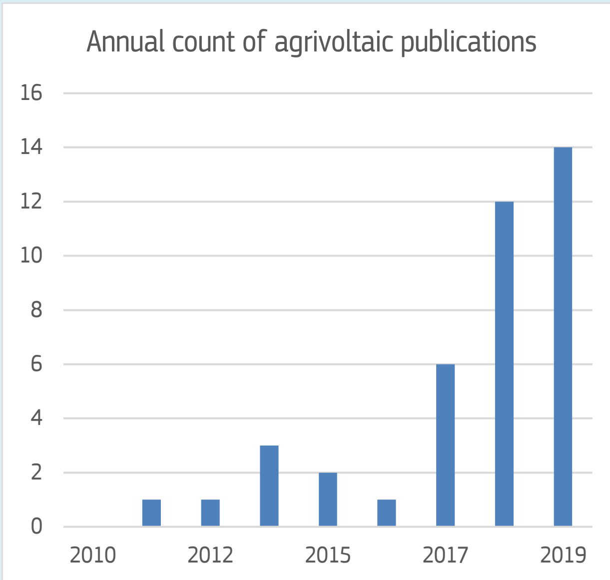
Examples of news articles from mainstream press and the web

- https://www.bloomberg.com/news/articles/2014-05-26/solar-farmers-in-japan-to-harvest-electricity-with-crops
- https://cleantechnica.com/2018/06/21/fraunhofer-experiments-in-chile-and-vietnam-prove-value-of-agrophotovoltaic-farming/
- https://www.dw.com/en/solar-energy-from-the-farm/a-19570822
- https://www.forbes.com/sites/enriquedans/2019/09/17/its-that-light-bulb-moment-time-for-a-radical-rethink-of-power-generation-based-on-renewables/#68a2f3a91697
- http://www.iran-daily.com/News/237228.html
- https://www.pv-magazine.com/2020/03/31/a-good-year-for-solar-agrivoltaics-in-vineyards/
- https://www.pri.org/stories/2018-06-08/energy-and-food-together-under-solar-panels-crops-thrive
- https://www.scientificamerican.com/article/farms-can-harvest-energy-along-with-food/
- https://www.wired.com/story/family-farms-try-to-raise-a-new-cash-cow-solar-power/

Literature scan

Ref.	DOI	Scope	Approach	Ref.	DOI	Scope	Approach
[1]	10.1016/j.rser.2012.04.002	System	FT	[31]	10.1016/j.seta.2017.08.004	System	TEA
[2]	10.1016/j.landurbplan.2017.10.011	System	CS	[32]	10.1109/PVSC.2018.8548119	PV	Modeling
[3]	10.1007/s13593-019-0581-3	Structure	Modeling	[33]	10.17660/ActaHortic.2018.1227.28	PV & crops	Modeling
[4]	10.1016/j.jenvman.2018.08.013	Land	Modeling	[34]	10.1111/cuag.12046	System	CS
[5]	10.1016/j.resconrec.2018.06.017	Land	Modeling	[35]	10.1016/j.agrformet.2013.04.012	Crops	FT
[6]	10.1016/j.apenergy.2017.09.113	Light	FT	[36]	Santra, P., IJRER Vol 7, No 2 (2017)	System	Modeling
[7]	10.1016/j.apenergy.2018.10.019	Light	Modeling	[37]	10.1016/j.renene.2011.03.005	System	Modeling
[8]	10.1088/1755-1315/170/4/042069	Light	Modeling	[38]	10.1016/j.rser.2015.10.024	PV & crops	Modeling
[9]	10.1109/ICSIMA.2018.8688801	Heat	FT	[39]	10.1016/j.renene.2019.02.048	System	Review
[10]	10.11591/ijeecs.v17.i2.pp858-867	Heat	FT	[40]	10.1038/s41893-019-0309-z	System	Review
[11]	10.3390/environments6060065	Structure	FT				
[12]	10.17660/ActaHortic.2017.1152.32	Heat	FT				
[13]	10.17660/ActaHortic.2017.1152.13	Structure	FT				
[14]	10.1364/AO.54.010232	PV	Experiment				
[15]	10.1063/1.5118014	PV	FT				
[16]	10.1038/s41598-019-47803-3	PV	Modeling				
[17]	10.1016/j.solener.2017.06.044	PV	Review				
[18]	10.1063/1.5118010	Crops	FT				
[19]	10.1109/PVSC.2018.8547609	Crops	Modeling				
[20]	10.1371/journal.pone.0203256	Water	FT				
[21]	10.1016/j.agwat.2018.07.001	Water	FT				
[22]	10.5194/hess-22-1285-2018	Water	Modeling				
[23]	10.1016/j.eja.2013.05.004	Water	Mod.&FT				
[24]	10.1038/s41893-019-0364-5	PV & crops	FT				
[25]	10.1016/j.eja.2012.08.003	Crops	Modeling				
[26]	10.1080/23299460.2019.1647085	System	Survey				
[27]	10.1002/tqem.21629	System	CS				
[28]	10.1016/j.apenergy.2018.03.081	System	CS				
[29]	10.35940/ijitee.L2497.1081219	System	Review				
[30]	10.1088/1755-1315/146/1/012002	System	TEA				



FT: Field Testing; CS: Case Study; TEA: Techno-Economic Assessment

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i https://iea-pvps.org/wp-content/uploads/2020/02/5319-iea-pvps-report-2019-08-lr.pdf

ii https://www.ise.fraunhofer.de/en/press-media/news/2019/aqua-pv-project-shrimps-combines-aquaculture-and-photovoltaics.html

iii Communication by the European Commission: The European Green Deal. COM(2019) 640 final

iv https://www.solarpowereurope.org/how-agri-pv-can-support-the-eu-clean-energy-transition-in-rural-communities/

v https://ec.europa.eu/jrc/en/research/crosscutting-activities/foresight

vi BOELMAN E, CARLSSON J, CONTOR L, KANELLOPOULOS K, MARMIER A, RUIZ CASTELLO P, SOMERS J, UIHLEIN A, Structured assessment of Agri-PV, European Commission, Petten, 2020, JRC120505

vii https://etip-pv.eu/events/etip-pv-conference/save-date-etip-pv-annual-conference-i3pv-integrated-innovative-intelligent/

viii http://www.agrivoltaics-conference.org/home.html

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